Experimental Investigation of Performance and Exhaust Emission of Four Stroke Spark Ignition Engine Using Ethanol Blending

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Abstract

This paper deals with experimental investigation of performance and exhaust emission of four stroke spark ignition engine using ethanol blending. The engine performance parameters like torque, power and fuel consumption rate were investigated. Also, for the emission test carbon dioxide (CO_2), carbon monoxide (CO) & hydrocarbon (HC) were considered. All experiments were carried out for different proportions that are EB0, EB5, EB10, EB15 and EB20 at various engine speeds. The research is mainly concentrate on two aspects one is to reduce the emissions of the engine and is to minimize the dependency on the conventional fuels and other is to improve the performance of the engine. Ethanol blending with gasoline gives almost the same results as gasoline used as a fuel, by using blend of ethanol and gasoline. The power of the engine and specific fuel consumption slightly increases due to low calorific value of the blend, while harmful emission like CO and HC decreases as more oxygen atom are available for combustion, and the carbon dioxide content increases due to complete combustion. The obtained results have shows that, the blend EB20 gave the best performance and is closest to gasoline fuel. Also reduction in exhaust emission has been reported.

Keyword*- SI Engine, Ethanol, Blending, Performance, Emission*

1. Introduction

The demand of fossil fuels increases daily due to the incredible growth of both society and industry. This issue could cause a panic of energy shortages due to the depletion of reserves and political conflicts in the Gulf region [1]. Hence, this imminent lack issue needs other sources of fuel to replace conventional fuel by an alternative functional fuel to reduce dependence on fossil fuels [2, 3].

Ethanol considers one of the most important alternative fuels which have the potential to replace fossil fuels because it is liquid and has similar chemical properties to that of conventional fuel properties [4]. Octane number in ethanol is higher than that of gasoline that is the reason behind its usage in engines to improve the Antiknock phenomenon [5]. The use of pure ethanol as fuel in engines requires some modification in engine, while there is no need for such modification in case of using ethanol and gasoline mixture as a fuel [6, 7]. The most of the previous studies tested a solo fuel type, even the studies impressed a dual fuel types didn't pay a tension to a mixture preparation procedure. Hence, this study examines the effect of mixing ethanol fuel with gasoline on the performance of the spark ignition engine and its exhaust emissions.

2. Literature Survey

James W. G. Turner et al. [8] had performed the experiment as alcohol fuels for spark-ignition engines: performance, efficiency, and emission effects at mid to high blend rates for ternary mixtures new findings are

presented for high-load operation in a dedicated boosted multi-cylinder engine test facility, for operation in modified production engines, for knock performance in a single-cylinder test engine, and for exhaust particulate emissions at part load using both the prototype multi-cylinder engine and a separate single-cylinder engine. Furthermore they are consistent for the iso-stoichiometric formulations, with a suggestion that within such GEM blends increased methanol content tends to lower NOx emissions further.

Mortadha. K et al. [9] studied fossil fuels used in internal combustion engines are among the largest contributors to environmental degradation, and this fuel has a high economic cost, so the need to use alternative fuels with less environmental impact and less cost-effective cost. This study provides a practical study comparing the use of LPG and gasoline in terms of performance and emissions from the four-stroke spark ignition, single cylinder, air cooled with a constant pressure ratio and variable-speed 1500–2500 rpm. A difference in volume efficiency, the brake thermal efficiency, fuel consumption and emissions of gases (HC, NO_x, CO_2, CO) has been measured that results have shown improved fuel consumption and thermal efficiency when using LPG fuel compared to pure gasoline. In contrast, the volume efficiency showed negative results when using LPG.

Sumit Taneja et al. [10] had analyzed of the engine characteristics of a variable compression ratio si engine fuelled with various gasoline-ethanol blends, This study investigated that the effects of ethanol-blended gasoline on emissions characteristics of a single–cylinder Spark Ignition (SI) Engine for different compression ratios. The three blends (E5, E10, and E15) were prepared in the laboratory. No modifications on the engine and its parts have been made. Moreover, no major problems like knocking were encountered during the engine operation.

Narayanan Kannaiyan Geetha et al. [11] had studied ethanol as gasoline blend on spark ignition engine, this experiment was based on effect of ethanol blend on spark ignition engine and a mathematical tool is proposed based on multi attribute decision making approach to select optimal combination of operating parameters of a variable compression ratio multi fuel engine considering objective, subjective and integrated weights of attributes. Test fuels used were ethanol-gasoline blends having ethanol in proportions of 10, 20, 30 and 40 volume %. The compression ratio was varied as 6, 7, 8 and 9. The result of proposed method shows that the combination of compression ratio 6, ethanol-gasoline blend 30 vol % at a load of 75 % is found to the best choice from among other trails and was validated using graph theory matrix approach.

A.A. Yusuf et al. [12] studied the bio-alcohol has the potential to be used as an alternative to fossil fuels to reduce the total exhaust emissions from spark-ignition engines. This paper reviewed the most recent experimental studies on fundamental effects of performance, emissions and some combustion characteristics in SI engines. It also provides a guideline for suitable ethanol-gasoline and methanol-gasoline blend rates. Investigations were performed on different engines, operating conditions and rates of fuel blends with varying engine speeds. Most of the results showed that ethanol-gasoline has more benefits compared to methanol-gasoline in terms of exhaust emissions, engine power, and torque output, especially at low engine speed. The small differences in properties between ethanol-gasoline and methanol-gasoline blends are enough to create a significant change in the combustion system.

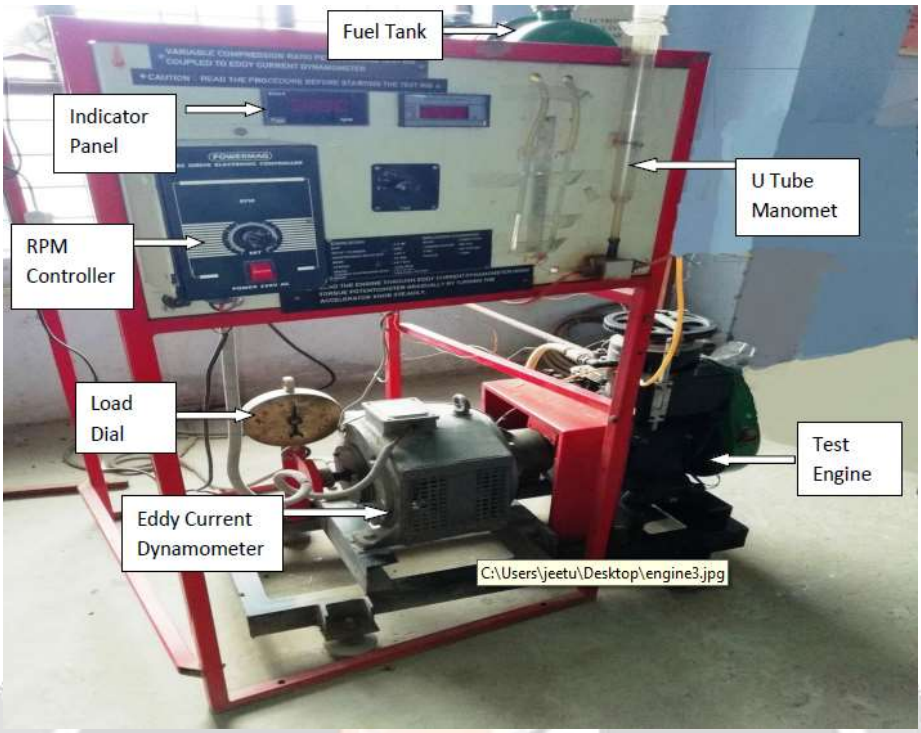


Fig.3.1 Engine Setup

3. Experimental Set-Up

The schematic diagram of experimental setup is shown fig.3.1. The setup consists of single cylinder engine coupled with eddy current dynamometer. The dynamometer is used to load and unload the engine as per experiment requirement. In order to measure revolution of the engine shaft a sensor is coupled with the shaft to count the rpm of the shaft, and for measuring various exhaust the test engine is connected with a exhaust sensor and a PUC vehicle's (Pollution under Control) test sensor. A sensor is coupled with the exhaust pipe outlet to sense various contents of exhaust gas and sent the result to CPU which in turn shows the results on the monitor screen. For cooling external jacket of the engine is coupled with water source. And the fuel tank is coupled with engine to supply the fuel to the cylinder.

After, all setup completion the experiment is carried out using different fuel petrol and blends of the petrol and ethanol i.e. EB0, EB5, EB10, EB15 and EB20 and the outcomes are being tabulated.

4. Results and Discussions

The experiment was conducted on five types of ethanol biodiesel blending ratio (ethanol biodiesel blended with diesel) that are EB0, EB5, EB10, EB15 and EB20 tested on diesel engine. The experiment was carried at Internal Combustion Engine Laboratory of Radharaman Institute of Technology & Science, Bhopal.

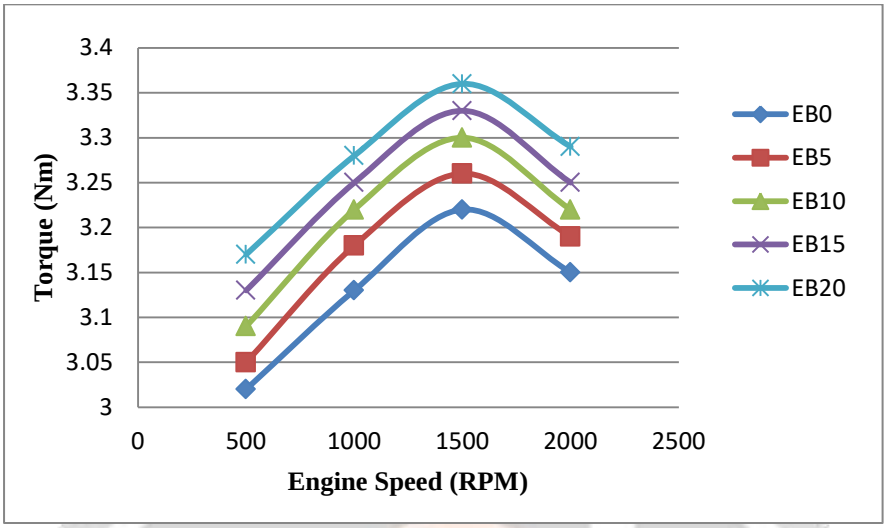
The parameters that have been tested for comparing six types of ethanol biodiesel blending ratio are performance and emission tests. The performance and emissions test for the five types of fuel were tested at different speed of 500 rpm, 1000rpm, 1500rpm and 2000rpm. Also, for the emission test carbon dioxide (CO_2), carbon monoxide (CO) & hydrocarbon (HC) were considered. The performance and emissions test for the six types of fuel were analyzed and results obtained are graphically presented.

4.1 Engine Performance Analysis for Ethanol Blending Ratios

The result and data for all types of ethanol blended fuels have been recorded include torque, power and fuel consumption rate for the performance tests. The averages of all data for engine performance analysis are tabulated and graphically presented below.

4.1.1 Comparative analysis of torque at various engine speeds for different ethanol blending ratios

Variation of torque and engine speeds for different blending ratios i.e. EB0, EB5, EB10, EB15 & EB20 is shown in graph 4.1.

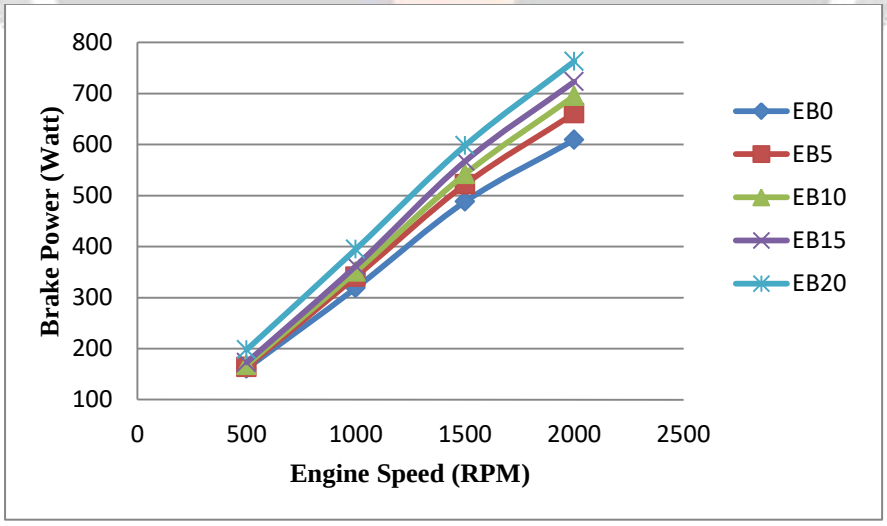


Graph 4.1 Variation of torque and engine speeds for different blending ratios

Graph 4.1 shows that the torque has increased as the blending ratio increased. For a fixed engine load, a higher throttle opening can provide more fuel for burning, i.e. more energy input. Therefore, the torque output is increased with the increase of the throttle valve opening, i.e. increased speed. Maximum torque was observed for EB20 blending ratio and minimum torque at EB0. Hence from the obtained results it can be said that as blending ratio increases; torque for spark ignition engine also increases. Furthermore, it has also observed after 1500 rpm torque suddenly decreased for increasing engine speeds.

4.1.2 Comparative analysis of brake power at various engine speeds for different ethanol blending ratios

Variation of brake power and engine speeds for different blending ratios i.e. EB0, EB5, EB10, EB15 & EB20 is shown in graph 4.2.



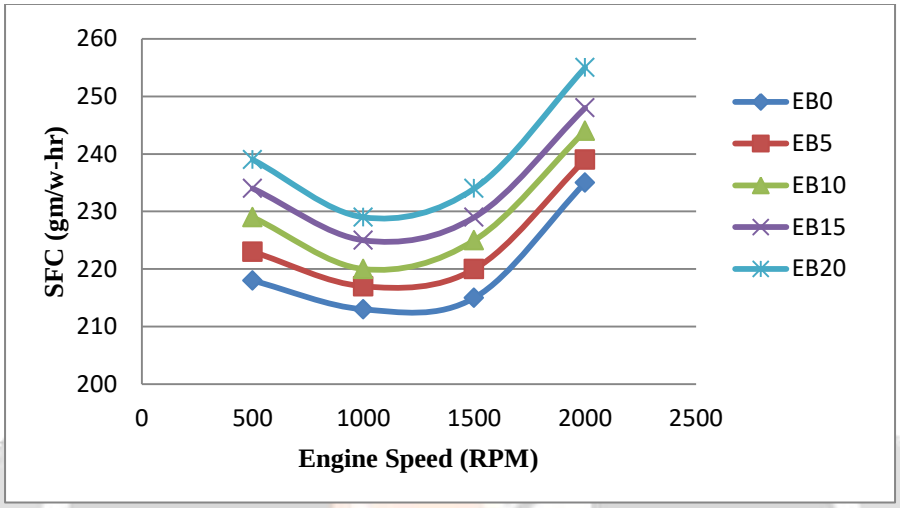
Graph 4.2 Variation of brake power and engine speeds for different blending ratios

Graph 4.2 shows that brake power has increased as the blending ratio increased. Since as the blending ratio increases i.e. when ethanol is added to the blended fuel, it can provide more oxygen for the combustion process and leads to the so called “leaning effect” [12]. Maximum brake power was observed for EB20 blending ratio and minimum brake power for EB0. Hence from the obtained results it can be said that as blending ratio increases brake power for spark ignition engine also increases. Also as the engine speed increase brake power also increases.

Furthermore, at higher blend ratio the fuel droplet size is particularly fine due to higher evaporation rate. This allows more air entrainment during the injection process, promoting a fast combustible mixture formation [10].

4.1.3 Comparative analysis of specific fuel consumption at various engine speeds for different ethanol blending ratios

Variation of specific fuel consumption and engine speeds for different blending ratios i.e. EB0, EB5, EB10, EB15 & EB20 is shown in graph 4.3.



Graph 4.3 Variation of brake specific fuel consumption and engine speeds for different blending ratios

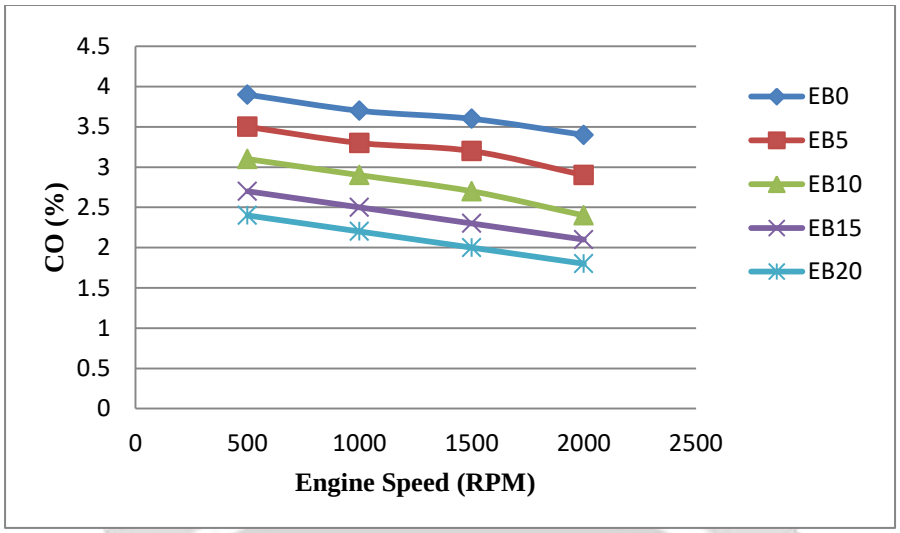
Graph 4.3 shows that specific fuel consumption has decreased as the engine speed increased from 500 rpm to 1000 rpm for different blending ratio; and have increased after 1500 rpm. However, theoretical air-fuel ratio of gasoline is 1.6 times that of ethanol, therefore the bsfc should be increased with the increase of ethanol content [12]. Hence from the obtained results; it can be said that as blending ratio increases brake specific fuel consumption initially decreases, but further it increases as the engine speed increases for spark ignition engine as the contribution of "leaning effect" of ethanol [11].

4.2 Engine Emission Analysis for Ethanol Blending Ratio

For the emission tests, the experimental data for all types of ethanol blending ratio have been recorded including carbon monoxide (CO %), carbon dioxide (CO^2 %) & hydrocarbon (HC %). The average of the data for engine emissions analysis was stated in the following table in appendices.

4.2.1 Comparative analysis of carbon monoxide at various engine speeds for different ethanol blending ratios

Variation of specific fuel consumption and engine speeds for different blending ratios i.e. EB0, EB5, EB10, EB15 & EB20 is shown in graph 4.4.



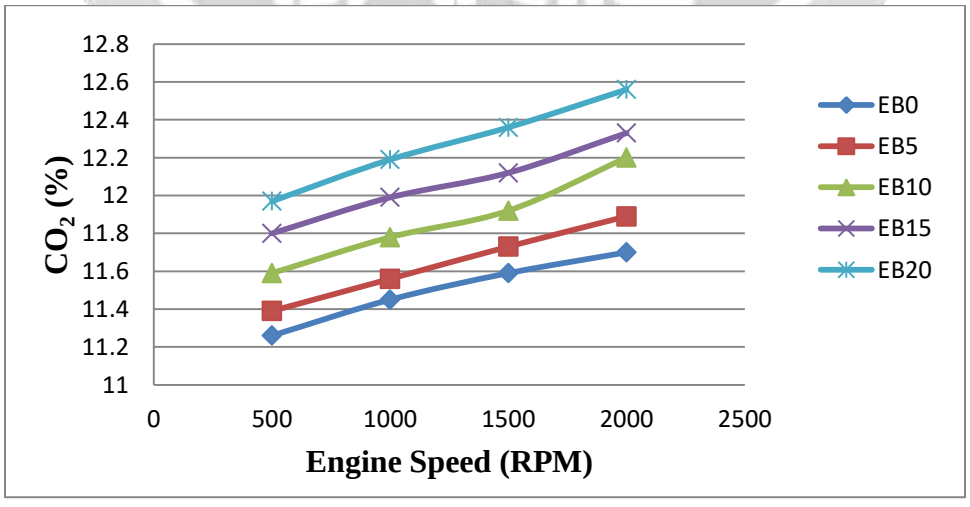
Graph 4.4 Variation of carbon monoxide and engine speeds for different blending ratios

Graph 4.4 shows that percentage emission of carbon monoxide decreases with the increase in ethanol blending ratio, which is believed due to a more complete combustion, occurred. Also, ethanol contains an oxygen atom in its basic form; it therefore can be treated as a partially oxidized hydrocarbon. When ethanol is added to the blended fuel, it can provide more oxygen for the combustion process and leads to the so called "leaning effect" [10]. Owing to the leaning effect, carbon monoxide will decrease tremendously. The EB20 has the lowest percentage of carbon monoxide emission. The carbon monoxide emissions are greatly dependent on the air-fuel ratio. At higher blend ratio, the fuel droplet size is particularly fine due to higher evaporation rate. This allows more air entrainment during the injection process, promoting a fast combustible mixture formation. Furthermore, increase in percentage of ethanol blending leads to decrease in percentage of carbon monoxide emission [10].

4.2.2 Comparative analysis of carbon dioxide at various engine speeds for different ethanol blending ratios

Variation of carbon dioxide and engine speeds for different blending ratios i.e. EB0, EB5, EB10, EB15 & EB20 is shown in graph 4.5.

Graph 4.5 shows that percentage emission of carbon dioxide increase with increase in ethanol blending ratios. Overall, the trend shows that the carbon dioxide emissions gradually increased when the engine speed increases. This indicates that when the engine speed increases, the combustion process would become more complete, thus completing the oxidation of carbon monoxide to carbon dioxide [11].



Graph 4.5 Variation of carbon dioxide and engine speeds for different blending ratios

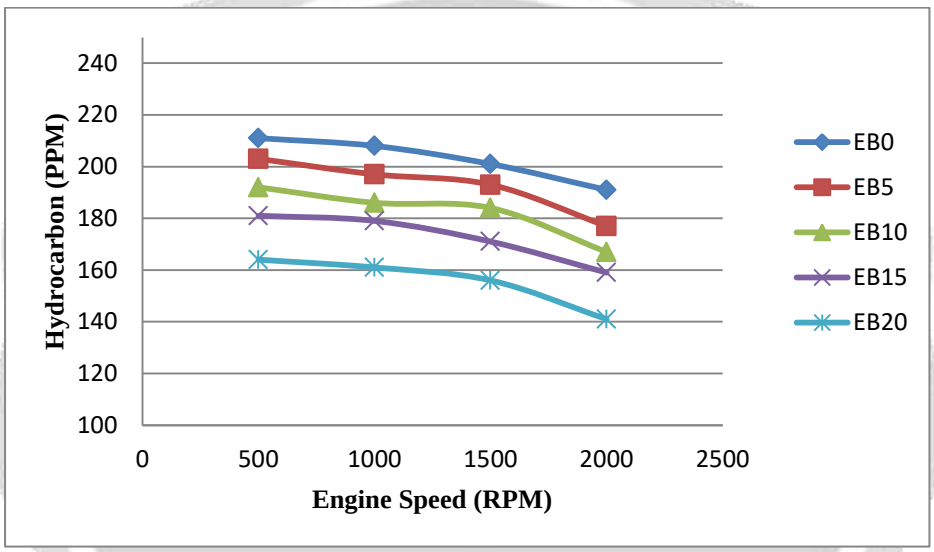
Further, ethanol contains an oxygen atom in its basic form; it therefore can be treated as a partially oxidized hydrocarbon. When ethanol is added to the blended fuel, it can provide more oxygen for the combustion process and leads to the so called "leaning effect". Owing to the leaning effect, carbon monoxide will decrease tremendously

The E20 has the highest percentage of carbon dioxide emission compared with the other blended ratios and gasoline fuel due to the high intensity of oxygen in the blended fuel. This level of oxygen in the blended fuel could promote a better combustion process.

According to Balki et al. [13], the high oxygen ratio in alcohols could improve the combustion efficiency and caused higher carbon dioxide emissions. Due to more complete combustion with sufficient oxygen and ignition timing, the carbon residue tends to combine with oxygen to form carbon dioxide. Unlike with the incomplete combustion with less oxygen content, the carbon residue tends to combine with oxygen to form carbon monoxide [10].

4.2.3 Comparative analysis of hydrocarbon at various engine speeds for different ethanol blending ratios

Graph 4.6 shows that the concentration of hydro carbon emission decreased with increase in ethanol blending ratio.



Graph 4.6 Variation of hydrocarbon and engine speeds for different blending ratios

The E20 has the lowest concentration of hydro carbon emission. Also it has been observed that as the engine speed increases concentration of exhaust gas emission decrease, because of complete combustion, due to the presence of more oxygen in ethanol blended fuel which further, leads to decrement in the concentration of hydro carbon [11]. Furthermore, increase in percentage of ethanol blending leads to decrease in concentration of hydro carbon emission.

Also, ethanol contains an oxygen atom in its basic form; it therefore can be treated as a partially oxidized hydrocarbon. When ethanol is added to the blended fuel, it can provide more oxygen for the combustion process and leads to the so called "leaning effect" [10]. Owing to the leaning effect, carbon monoxide will decrease tremendously.

5. Conclusions

The experimental investigation of performance and exhaust emission of four stroke spark ignition engine using ethanol blending has been done. The conclusion drawn from the present study are:

1. Combustion of ethanol-gasoline blends slightly increases engine power and specific fuel consumption of the engine due to low calorific value of ethanol without modifying the engine.
2. Ethanol-gasoline blends increases the engine torque due to high octane number of ethanol at higher percentage of blending as ethanol has higher anti-knock quality

3. CO emission of the engine decreases drastically due to leaning effect caused by the ethanol addition as more oxygen atom are available for combustion at higher engine speed and CO_2 increases due to complete combustion of the fuel.
4. HC emission decreases only in some working conditions of the engine. Usually at higher percentage of ethanol-gasoline blending.
5. The ethanol blending in gasoline providing better results than gasoline for the same output of work.
6. The optimal blending percentage seems like 20% as the most graphs shows the better results at 20% ethanol blending with gasoline.
7. The blending till 20% of the ethanol in the gasoline does not require any significant modification in the existing engine.

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