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# Influence of Ethanol Blending On Performance and Exhaust Emissions of Four Stroke Spark Ignition Engine

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**Abstract-** This work deals with the blending of ethanol and gasoline in various proportions to reduce the consumption of gasoline and to reduce the dependability on the petroleum product such as petrol. The aim of this work is to study about the blending of ethanol and gasoline product for reducing the amount of gasoline being combusted for the same output of a 4-stroke single cylinder spark ignition engine. The scope of this research is to reduce the consumption of petrol as we know the resources of gasoline product are limited and get exhausted soon if used with the same speed. After all equipment has been setup the blending of ethanol 5%,10%, 15% and 20% ,with petrol has done and the results of various experiments has been recorded and tabulated. Alternative fuels for engines have become very important to increase the environment protection concern and to reduce the dependency on the conventional fuels such as petroleum products. 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-di-oxide content increases due to complete combustion.

**Keywords:-**Blending,4-Stroke petrol engine, Alternative fuels, Conventional fuels.

## 1. INTRODUCTION

The energy consumption of the world was estimated about 575 quadrillion BTU and at the end of 2015 and the energy consumption of the world will be increased to 736 quadrillion BTU at the end of 2040 [16] and the liquid form of fuel such as petroleum would be the largest source of energy. As the energy demand continue to climb the global emissions increases as well, therefore to reduce the dependability on petroleum product for energy production and to safeguard the concentration of atmosphere, world has to switch to find the alternate of petroleum product.

Numbers of the field for study in automobile where numbers of researchers are working on various aspects of the engine and fuel on very micro level to improve the performance of the engine. Blending of fuel is also a extensive aspect for study to improve the performance of the engine, there are two major advantages of blending one is to reduce the gasoline consumption and the other is to reduce the amount of harmful gaseous to the atmosphere. The scarcity of petroleum based fuels and increase in carbon monoxide hydrocarbons, nitrogen oxides particulates emissions and carbon dioxide lead to development of clean burning renewable alternatives fuels. Generally, gaseous fuel emits low level of pollutant to the atmosphere. Gaseous fuels shows wider range of ignition range and can easily form homogeneous mixtures with air to promote complete combustion. Even very lean mixtures can be used. Moreover, gaseous fuels have high hydrogen to carbon ratios, which will lead to low carbon-based emissions.

Engineers around the world, trying to develop the engine and fuel such that the harmful emissions generated through it would be let into the surrounding without serious impact on the environment. Today the main part of environment pollution is the exhaust of transport vehicle and large industries around 30 billion tons of $CO_2$ is added to the atmosphere per year. It is not possible to cut down the numbers of the vehicles and to stop the industries to gain ground, therefore government has set many regulatory laws to reduce the emissions of transport vehicle and industries. Because of the depletion of fossil fuel, it is necessary to find out other alternative fuels which are possible to substitute for gasoline fuel. Some of them are liquefied petroleum gas (LPG), natural gas (CNG, LNG), biodiesel, alcohol fuels (methanol, ethanol, butane), hydrogen, diethyl ether (DME), synthesis gas. In recent years, blends of ethanol/gasoline used as fuels for gasoline engine have been studied and widely utilized in many countries around the world such as the U.S. (E10), Brazil (E20), Thailand (E10)... The use of these fuels is not only a potential solution for satisfying the fuel demand but also for reducing emissions from vehicles. Many studies showed that fuelling ethanol/gasoline blends for gasoline engine can improve engine performance, reduce HC and CO, but the trend of Knox may vary depending on specific situations.

**1.1 *Alternate fuels***

There are many alternate fuels available today such as alcohols, biogas, hydrogen, LPG etc. but one of the most favorable alternate fuel among all available is ethanol (alcohol) due to its almost same characteristics as gasoline, further there is no need of engine modification at low blending percentage of ethanol with gasoline. Therefore in this experiment we have used ethanol as an alternative fuel with gasoline.

**1.2 *Ethanol as an alternative fuel***

Ethanol has a higher octane number than that of gasoline. Therefore, it will allow the alcohol to have higher compression ratios, and increased the thermal efficiency. However, a significant disadvantage of alcohol was they had lower energy content compare with gasoline. Other than that, alcohol has lower calorific value compare with gasoline, and causing it to produce less power compared with gasoline.

Usage of bio-ethanol as a oxygenate fuel in spark ignition engine resulting an effect on reducing hydrocarbon emissions, even it can be minimize products of $NO_x$ emission if bio-ethanol is used in high concentration, as well as it has a significant impact on decrease of greenhouse gas (GHG) effect. The drawback of ethanol is just that the generated power is lower than gasoline, so the suitable on bio-ethanol injection is required to get the equivalent power with gasoline. Octane rating of bio-ethanol is higher than that of the conventional gasoline(petrol), so the high compression ratio can be employed to increasing the torque and power as a compensation in low of heating value of bio-ethanol. Application of bio-ethanol as a fuel is a solution toward increases of greenhouse gas (GHG) and global warming. Experimentally, the oxygen content of bio-ethanol was predicted influence to reducing hydrocarbon emission significantly, even though its exhaust gas is less toxic.

## 2. LITERATURE REVIEW

**Alvydas Pikūnas et al[1]** Influence of composition of gasoline – ethanol blends on parameters of internal combustion engines- The purpose of this study is to investigate experimentally and compare the engine performance and pollutant emission of a SI engine using ethanol–gasoline blended fuel and pure gasoline. It is found that when ethanol is blended with gasoline the heating value of the blend decreases, whereas on the other hand the octane rating increases. The test results shows that when ethanol is blended with gasoline the harmful of emissions such as CO, HC, CO2 etc decreases and engine power and efficiency is increases slightly (1).

**F. M. Salih et al[2]** The Influence of Gasoline/Ethanol Blends on Emissions and Fuel Economy-A 1117cc Ford Valencia SI engine was used to investigate the influence on emissions of relatively large (10-30%) additions of ethanol to gasoline. The ethanol was shown to extend the lean burn range and improve the specific energy consumption in the lean burn region. Addition of ethanol significantly reduced NOx and CO by over 50% and increased slightly HC and condensable hydrocarbons, but had little effect on NMHC. (2)

**Pang et al[3]** found that CO emission was slightly reduced (1.5–6%) from 10% (E10) ethanol blended gasoline in comparison with gasoline (RN95 -E0). The ethanol blended with gasoline provide more oxygen than gasoline thus enables more combustion of the ful resulting less CO emission (3).

**Mahesh M.Patil et al[4]** presented in their technical paper to analyze the performance, emission, and combustion characteristics of variable compression ratio (VCR), compression ignition (CI) engine using a suitable biodiesel as a fuel.(4)

**P.M. Darade et al[5]** presented in their technical paper the development of alternative fuels such as natural gases has become very essential because of the continuously decrease in the petroleum reserves and also their contribution for pollutants.(5)

**Ashok A. Mandal et al[6]** presented in their technical paper that fossil crude oil reserve was depleting fast will not last for a very long period. Hence there is a pressing need to find and develop new suitable ways to use alternative fuels driven by various factors such as cost, availability, performance and exhaust emissions as par with emission legislation. The major alternative fuels under consideration are propane, methanol, ethanol and natural gas

**H S Farkade et al**[7] have founded three alcohols in two parts. Comparative study of methanol, ethanol and butanol on the basis of blending percentage is first part, followed by investigation of oxygen role on the basis of oxygen percentage in the blend.

**Pang et al**[8] found that CO emission was slightly reduced (1.5–6%) from 10% (E10) ethanol blended gasoline in comparison with gasoline (RN95 -E0). The ethanol blended with gasoline provide more oxygen thangasoline thus enables more combustion of the ful resulting less CO emission (10).

**A. A. Abdel-Rahman et al**[9] Using different ethanol–gasoline fuel blends, a VARICOMP engine was used to study the effect of varying the compression ratio on SI engine performance. The test was done by using different percentage of ethanol blend up to 40% at different rpm and load.

**J.Zaldivar et al**[10] The current scholars are focusing on using lignocellulosic material as feedstock, otherwise known as "second-generation" production techniques. This includes agricultural residuals (e.g. wheat straw, corn stalks, soybean residues, and sugar cane biogases) forest residues, industrial waste (from the pulp and paper industry) and municipal solid waste.

**K. Manikandan**[11] studied different blend rates of ethanol blended with gasoline fuel for combustion in the engine and found that adding ethanol had reduced the CO and HC emissions to some degree.

**Marth EN Paloboran**[12] has found that on using ethanol-gasoline blend the formaldehyde, acetaldehyde and acetone emissions increases by 5-14 times comparatively gasoline. Even though the aldehyde emission increases by ethanol blending causes harmful effect far less than gasoline.

**Rong-Horng Chen et al**[13] has studied that the as the ethanol content increases in the blend the mixture of air-fuel becomes leaner at E5, E10, E20 and E30. The harmful emission like CO and HC decreases abruptly when ethanol is added more than 20% in the blend.

**A Y F Bokhary et al**[14] It is found that the results are showing that when ethanol is mixed, the carbon monoxide (CO) and carbon dioxide (CO2) emission concentrations in the engine exhaust decrease, while the nitric oxide (NO) concentration increases.

**Palmer**[15] used various blend rates of ethanol–gasoline fuels in engine tests. Results shows that for every 10% of ethanol addition there is a 5% increment in octane number also increases power output by 5%. He also indicated that 10% of ethanol addition to gasoline could reduce the concentration of CO emission up to 30%.

## 3. EXPERIMENTAL SETUP AND METHODOLOGY

The experimental unit consists of three systems, i.e. engine system, eddy current dynamometer (Load input system) and exhaust measurement system and is shown in the figure.

The schematic diagram of experimental setup is shown. 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 gas analyzer. A sensor is coupled with the exhaust pipe outlet to sense various contents of exhaust 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.

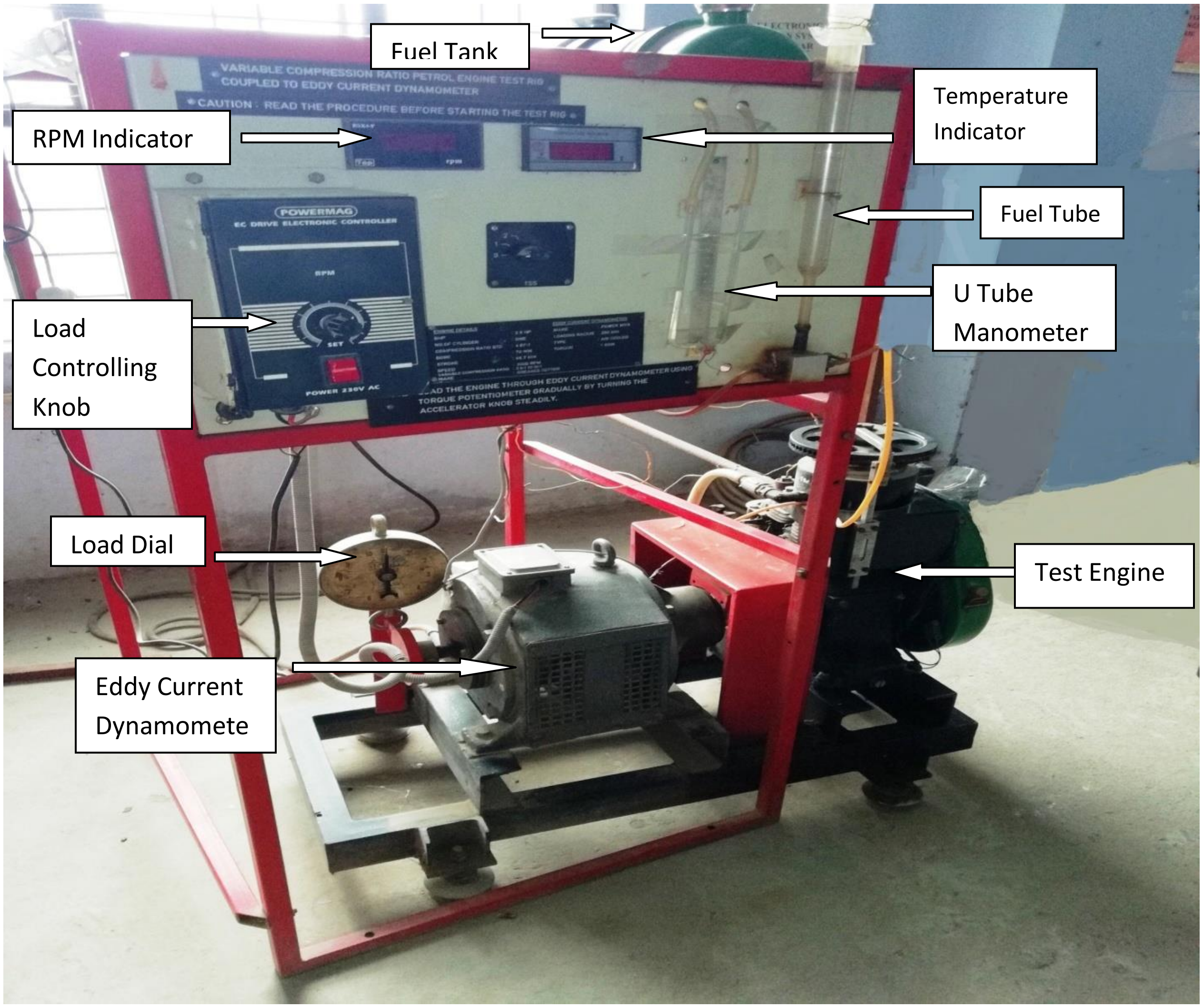



Fig. 1 Experimental set-up

Table 1.The engine used in the experiment has following specifications

| S. No | Specification | Values |
|---|---|---|
| 1 | BHP | 2.5HP |
| 2 | Rated speed | 3000rpm |
| 3 | No. of cylinders | 1 |
| 4 | Bore | 70mm |
| 5 | Stroke | 66.7mm |
| 6 | Power | 2.5kw |
| 7 | Lubrication oil | SAE-40 |

Blended Fuel is being used for the test the comparison of gasoline and ethanol is shown below in the table:

**3.1 Ethanol**

Ethanol is a form of an alcohol which is produced by crop based process and by fermentation of the sugars. The former process is more economical depending on the prevailing prices of petroleum and grain feed stocks. Almost all the countries around the world producing ethanol by former process.

Ethanol has a higher octane number than that of gasoline. Therefore, it will allow the alcohol to have higher compression ratios, and increased the thermal efficiency. However, a significant disadvantage of alcohol was they had lower energy content compare with gasoline. Other than that, alcohol has lower calorific value compare with gasoline, and causing it to produce less power compared with gasoline.

Properties of ethanol

- At room temperature ethanol is a colorless liquid with a characteristic odor.
- Ethanol is highly soluble in water in all proportions.
- Density of ethanol at $68^0$ F ($20^o$ C) is 0.789 g/ml.
- Boiling point of ethanol is $173.3^o$ F ($78.5^o$ C) and melting point is $-173.4^o$ F ($-114.1^o$ C)

The comparison of various properties of Ethanol and Gasoline fuel is summarized in Table. Ethanol has a wider flammability limit of 3.5-26 volume % as compared to 1.4-7.6 volume % for gasoline, and hence is on the richer side. A wide rich flammability limit may be useful because rich air: fuel ratios can be used to maximize power by injecting more fuel per charge.

Table 2.Comparison of petrol and ethanol

| S.No. | Character | Ethanol | Gasoline |
|---|---|---|---|
| 1 | Composition | C=51%<br>H=14%<br>O=35% | C=85%<br>H=15% |
| 2 | Molecular weight(kg/kmol) | 46.07 | 100-106 |
| 3 | Density(kg/m3) | 790 | 700-780 |
| 4 | Heating value(kj/kg) | 27.0 | 44.0 |
| 5 | Sp. Gravity | 0.794 | 0.7-0.8 |
| 6 | Octane number | 100 | 80-98 |
| 7 | Cetane number | 8 | 0-10 |
| 8 | Boiling temp. ($^o$C) | 78 | 27-254 |
| 9 | Freezing point ($^o$C) | -114 | -57 |
| 10 | Air fuel ratio | 9.0 | 14.7 |
| 11 | Ignition temp. ($^o$C) | 423 | 390-420 |
| 12 | Latent heat KJ/KG | 846 | 339 |

A wide flammability limit on the lean side is useful in extending the operating range of the lean burn engines. Gasoline is composed of a mixture of large number of hydrocarbons having boiling point ranging from $27^o$C to about 254 $^o$C. Ethanol in contrast has a BP of 78 $^o$C. The alcohols lack the light end fractions essential for cold starting of SI engines (Kremer, 1996), (Fikret and Bedri, 2004). Although ethanol itself has an RVP less than that of Gasoline, its addition to Gasoline markedly increases the RVP of the blend, which can lead to increased evaporative emissions. It is generally accepted that the peak RVP of ethanol blends occurs at around 5-10% ethanol concentration, and is about 6.5% above the RVP of neat Gasoline (Murphy and McCarthy, 2004).

The comparison of different fuel blends used in the experiment is shown below with their different properties.

Table 3.Comparison of fuels used in experiment

| Characteristics ⇨ / Fuel ⇩ | Density, Kg/L @ 15.6 $^o$C | API gravity, deg | Kinematic viscosity $mm^2/s$ at 30 $^o$C | Flash Point, $^o$C | Fire Point, $^o$C | Cloud Point, $^o$C | Heat of Combustion, MJ/L | Octane number |
|---|---|---|---|---|---|---|---|---|
| **Gasoline** | 0.7400 | 59.53 | 0.4872 | - | 25.0 | -22 | 34.84 | 93.2 |
| **E5** | 0.7311 | 58.89 | 0.4929 | - | 28.0 | >8 | 33.79 | 96.2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **E10** | 0.7396 | 57.10 | 0.5383 | - | 29.0 | >8 | 33.19 | 97.1 |
| **E15** | 0.7495 | 57.09 | 0.5619 | - | 29.1 | >8 | 32.91 | 98.6 |
| **E20** | 0.7541 | 55.95 | 0.6007 | 29.2 | 30.0 | >8 | 32.43 | 100.4 |

Gasoline and different blend of gasoline and ethanol are being used in the test. The different blends used in the test are as E5, E10, E15 and E20.

1. E5 stands mixture of 5% ethanol and 95% gasoline.
2. E10 stands mixture of 10% ethanol and 90% gasoline.
3. E15 stands mixture of 15% ethanol and 85% gasoline.
4. E20 stands mixture of 20% ethanol and 80% gasoline.

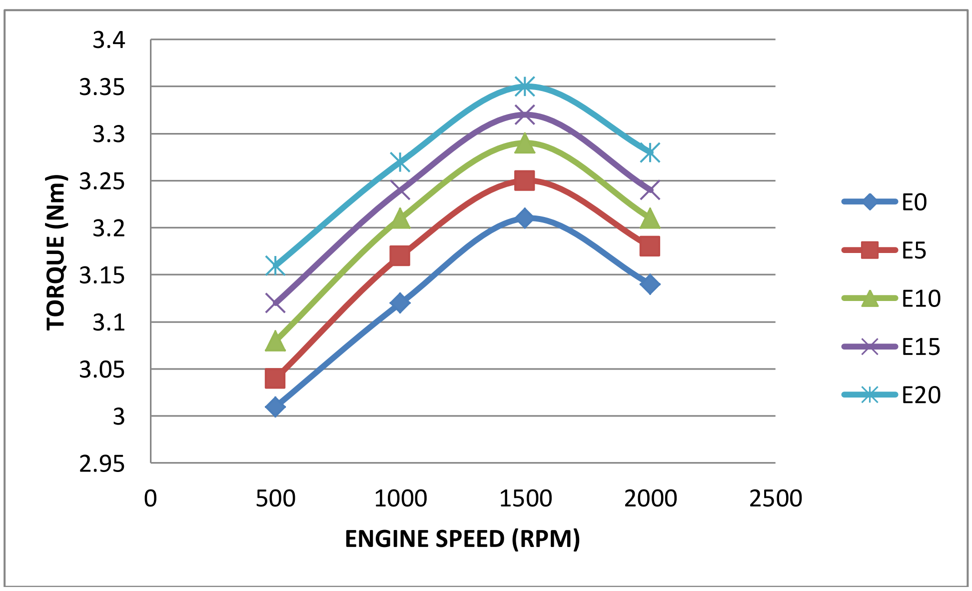
## 4. RESULTS AND DISCUSSION

The result grouped into two category i.e. the first one is performance analysis and the second one is exhaust emission analysis. In the former category deals with torque, brake power and specific fuel consumption. While the second category deals with the exhaust emissions such as CO, $CO_2$ and HC.

### 4.1 *Performance analysis*

**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. E0, E5, E10, E15 & E20 is shown in graph 4.1



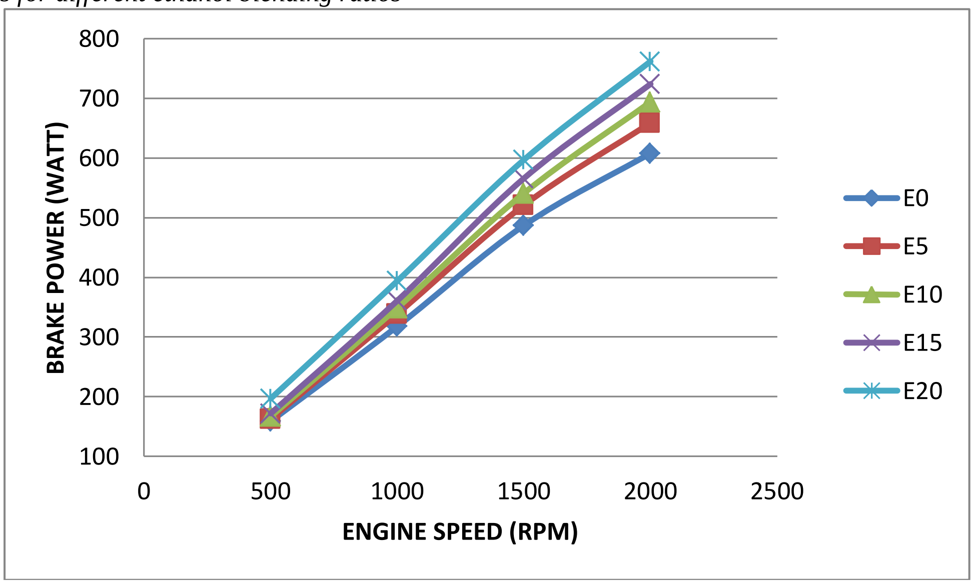

Graph 4.1 Variation of torque and engine speeds for different blending ratios

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 E20 blending ratio and minimum torque at E0. 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. E0, E5, E10, E15 & E20 is shown in graph 4.2

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" [11].



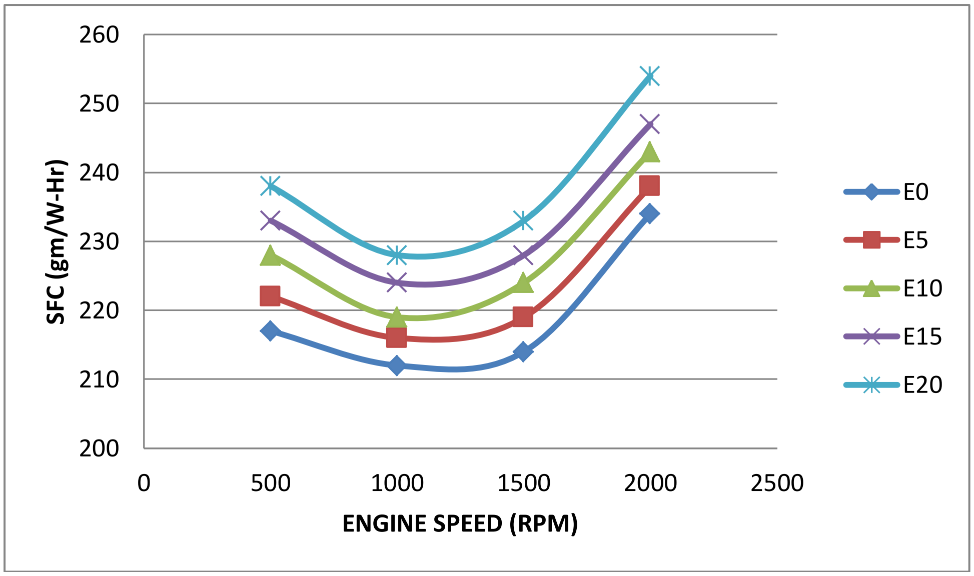

Graph 4.2 Variation of brake power and engine speeds for different blending ratios

Maximum brake power was observed for E20 blending ratio and minimum brake power for E0. 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. E0, E5, E10, E15 & E20



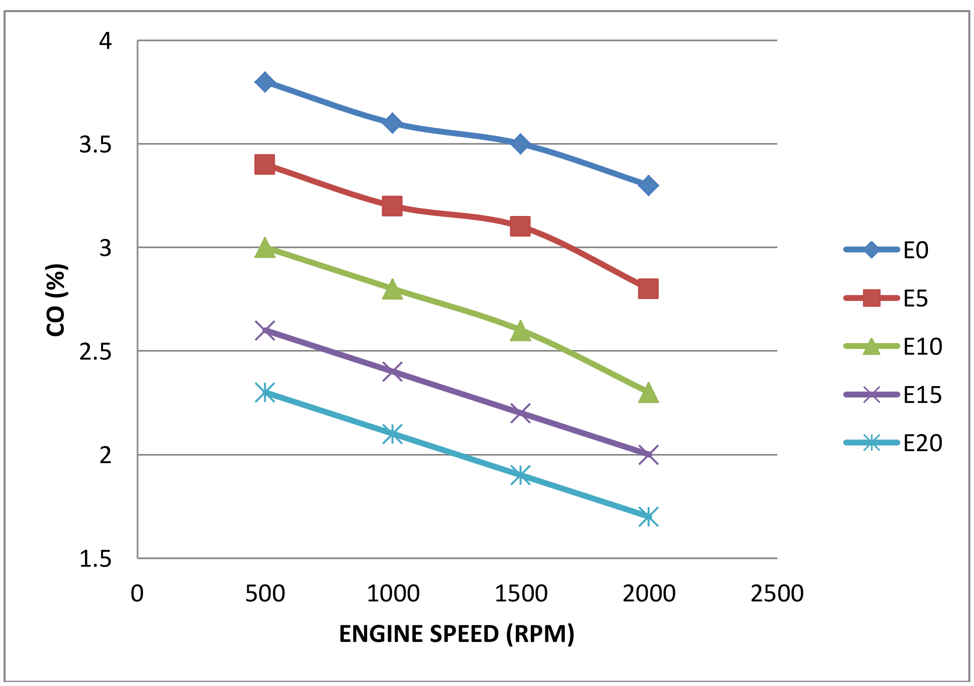

Graph 4.3 Variation of brake specific fuel consumption and engine speeds for different blending ratios

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 *Exhaust Emission analysis*

**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. E0, E5, E10, E15 & E20 is shown in graph 4.4

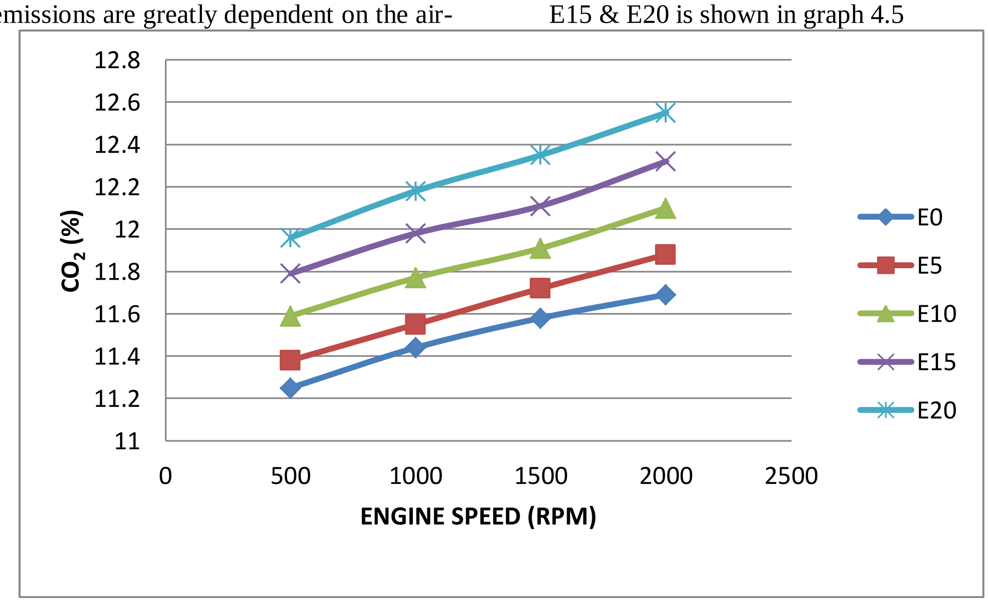


Graph 4.4 Variation of carbon monoxide and engine speeds for different blending ratios

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 E20 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. E0, E5, E10, E15 & E20 is shown in graph 4.5



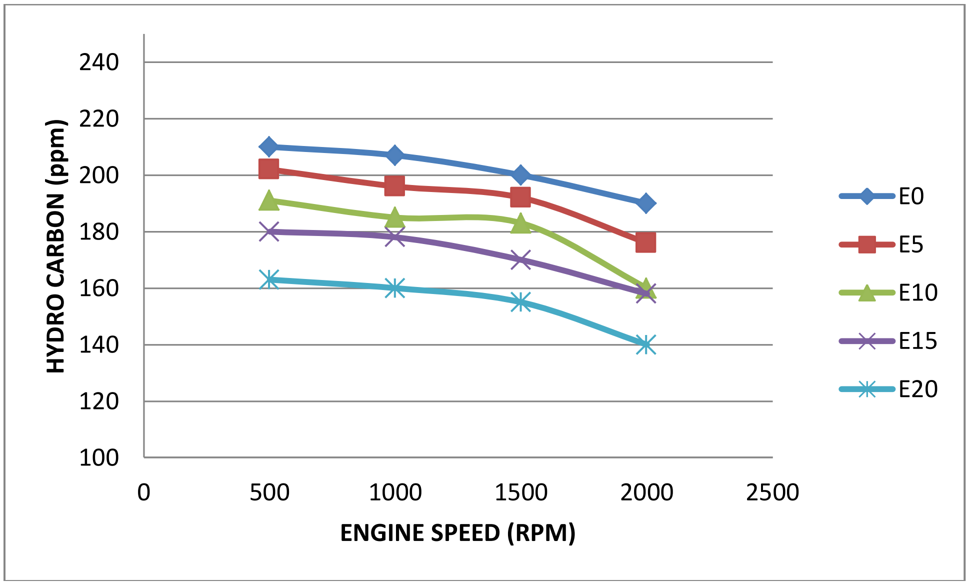

Graph 4.5 Variation of carbon dioxide and engine speeds for different blending ratios

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 [16]..

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

Variation of carbon dioxide and engine speeds for different blending ratios i.e. E0, E5, E10, E15 & E20 is shown in graph 4.6

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




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

## 5. CONCLUSION

The motive of this experiment is to investigate the effect of ethanol-gasoline blend on engine performance and pollutant emission. The test fuels that are used in experiment are pure gasoline (petrol) or E0, E5, E10, E15 and E20. The performance of the engine i.e. brake power, torque and specific fuel consumption and exhaust emissions i.e. carbon-mono oxide (CO), carbon-di-oxide ($CO_2$) and hydro-carbon (HC)are tested for all fuel blends.

In this experiment, gasoline and other all fuel blends are tested on different rpm i.e. 500, 1000, 1500 and 2000 rpm at constant load, and the outcomes of this test are summarized as follows

i. 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.
ii. 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.
iii. 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.
iv. HC emission decreases only in some working conditions of the engine. Usually at higher percentage of ethanol-gasoline blending.

In this test it is found that when ethanol-gasoline blends are used the engine power and fuel consumption of the engine slightly increases because of low calorific value of ethanol; CO emission decreases as ethanol addition causes the leaning effect; $CO_2$ emission increases due to complete combustion of the fuel; HC emission decreases only in some working condition of engine; ethanol has higher anti-knock characteristics thus improves torque.

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