Performance Characteristics of a Multi Cylinder MPFI Spark Ignition Engine using Ethanol–Petrol Blended Fuels

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CANDIDATE'S DECLARATION

I declare that the work presented in this thesis entitled "**Performance Characteristics of A Multi Cylinder MPFI Spark Ignition Engine Using Ethanol–Petrol Blended Fuels**" submitted to the Department of Mechanical Engineering, R D Engineering College, Ghaziabad (UP) (India) for the award of the **Master of Technology** Degree in **Thermal Engineering**, is my original work. I neither have plagiarized any part of the thesis nor submitted the same work for the award of any other Degree anywhere.

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[Abstract]

ABSTRACT

The goal of this study is to experimentally establish the ideal ethanol-gasoline fuel blend rate in order to increase a commercial SI engine's braking thermal efficiency. The engine performance in this study has been examined in terms of braking torque and brake-specific fuel consumption while varying the volumetric mixture ratio between 87.5-octane gasoline and 99.5 percent pure ethanol (E0, E10, E20, E30, E40, and E50). The experiment has been run at various engine speeds and intake-throttle opening percentages. Testing was done with a fixed compression ratio. The ignition time was adjusted for maximum engine torque and the relative air-fuel ratio was set to unity .According to the experimental findings, a proper ethanol-gasoline mixture ratio can increase engine torque, particularly at low engine speeds. When utilising E40 and E50 fuels, the engine should run between 58 and 73 percent of its working temperature (WOT) at a speed between 2000 and 2500 rpm. Additionally, this document offers recommendations for an appropriate ethanol-gasoline mix rate at particular engine loads and speeds.

Keywords: **Ethanol; Ethanol-gasoline blends; SI engine; Performance**

CHAPTER 1

INTRODUCTION

Petroleum-based fuel supplies are being quickly depleted due to the predominant usage of fossil fuels for energy generation. The necessity for the usage of regenerative fuels has increased due to the rapid decline in the future availability of fossil fuels and the requirement to reduce fuel-related emissions (Janet al., 2007). Traditionally, internal combustion engines have been powered by gasoline and diesel, both of which are fossil fuels whose production and burning result in the emission of pollutants that are bad for the environment and human health. The greenhouse gas emission from the combustion of petrol and other hydrocarbon fuels have been identified as the major cause of climate change and global warming (Igbo we et al., 2015).These environmental concerns and the desire to be less dependent on fossil fuel have intensified worldwide effortful production of biodiesel from vegetable organic materials and bioethanol from starch and sugar producing crops (EPA 2007). The limited nature of oil resources has made studies on alternative energy sources much more important in internal combustion engines in which oil products are used as energy source (Candace*et al.*, 2006;Hulwan and Joshi, 2011; Kannan*et al.*, 2011; Fahd *et al.*, 2013).

Biofuels such as bioethanol, a colorless liquid with mild characteristic odor can be produced by fermentation ofbiomass crops such as wheat, sugar beet, sugar cane, corn, raffia trunk, wood and wood-like plants (Park*et al.*, 2012; Guido *et al.*, 2013; Nwufo*et al.*, 2013; Nwufo*et al.*, 2014). Using bioethanol as fuel for spark ignition engine Has some advantages over petrol such as better anti-knock characteristics, better emission characteristics, improved brake thermal efficiency and volumetric efficiency (Al-Hassan, 2003; Seshaiah, 2010; Ananda and Savanna, 2010; Jitendra*et al.*, 2013). However, the oxygen content in ethanol reduces the heating value of theblends produced with petrol (Yucesu*et al.*, 2007; Nwufo*et al.*, 2013). The fact that ethanol is a renewable energy source with potential for sustained production and exploitation is another significant benefit of using it as fuel for internal combustion engines.

However, because of ethanol's high affinity for water, mixing it with gasoline can be problematic because phase separation could happen because ethanol and gasoline may not mix well. This problem can be prevented by using semi-polar co-solvents such as isopropanol (Al-Hassan, 2003) Guerrier*et al.*, 1995, Hsieh *et al*., 2002 and Wu *et al*., 2004 investigated the engine performance and the emission of spark ignition engine using various blends of ethanol – petrol fuels. The result showed that as ethanol content is increased, theheating value of the blended fuel decreased while the engine torque and brake thermal efficiency increases. Similarly, at high ethanol concentration HC emission, CO emission and fuel consumption decrease.

The largest industry in the world, the automotive industry uses a variety of fuels and is a convenient and dependable source of

both transportation and power generation. An automobile's power output mostly depends on the fuel that is burned during combustion. Basic liquid fuels like gasoline and diesel have been utilised extensively worldwide since the turn of the century. These fuels are made from crude oil, which is scarcely available globally. Because there are more cars on the road, there is a significant growth in the demand for fossil fuels, which causes the reserves of crude oil to quickly run out. Future energy crises will be impacted by this condition. In reality, demand will likely increase even more due to an increase in automotive production globally and increased demand from emerging economies. The demand for fossil fuels generally meets the need for transportation fuel. However, the availability of these fuels is dwindling, their costs are predicted to increase, and the environment is negatively impacted by the use of fossil fuels.

The use of fossil fuels is becoming more and more prevalent, yet burning them has an impact on the planet's ecology as well. Because there are more cars on the road, greenhouse gas emissions are rising. Despite the fact that many nations are working to reduce the levels of exhaust emissions from cars. For the greenhouse gas levels to be as low as possible, there is still much work to be done. Due to their compatibility with hydrocarbons, researchers are attempting to replace hydrocarbon fuels with alternative fuels including alcohols, ethers, and others. India imports over 75% of its total crude oil requirements. India imported over 189.238 MMT of crude oil in total in 2013–14, at a cost of nearly Rs. 8, 64, 875 Crore. 37.788 MMT of crude oil were produced overall in 2013–14.

In recent years, the consumption of crude oil in India has been increasing at an annual rate of 5-6 %. (Moping, 2014). If the use of alcohol as engine fuel is promoted in India, then in addition to saving money on foreign exchange, farmers will be encouraged to grow crops like sugarcane and potatoes in big quantities, which will boost the production of alcohol and improve the quality of the air. Due to increased deforestation and the number of automobiles, transportation-related air pollution will get much worse in the future. 13 Indian cities are listed among the top 20 most polluted cities in the world in a report by the World Health Organization on air pollution.

State governments are searching for an alternative to lowering air pollution. The concern over the emission issues with gasoline and diesel engines is another factor supporting the development of alternative fuels for internal combustion engines. The enormous number of automobiles, when combined with other air-polluting systems, is a significant contributor to the global problem with air quality. The way that emissions from car engines are reduced has undergone a significant amount of development. If a 35 percent improvement was made over a number of years, it should be noted that the world's automotive population was growing by 40 percent at the same time, which would cancel out the improvement. There have been numerous efforts made to enhance the net level of exhaust cleansing. However, more improvements are required to reduce the ever-increasing air pollution caused by the population of automobiles (Gamesman, 2010).

On December 24, 2009, the National Policy on Biofuels was approved by the Government of India (GOI). The policy empowers utilization of renewable energy resources as alternate fuel to supplement transport fuels and had proposed an demonstrative target to replace 20 percent of petroleum fuel consumption with biofuels (bioethanol and biodiesel) by end of 12th Five-Year Plan (2017)(TERI, 2007).

Prasad *et al.* (2007) mentioned that ethanol has less energy and heat value to gasoline, but it has the efficient combustion. While the engine produces better emissions, it uses more gasoline to travel the same distance. In place of the traditional additive (MTBE), which has a detrimental effect on human health, small amounts of ethanol added to unleaded gasoline serves as an octane booster? When added to diesel in an unaltered engine, ethanol can be blended with it up to 15%, significantly reducing visible smoke. Agarwal (2007) mentioned the drawback of using ethanol in the internal combustion engines. The internal components of an internal combustion engine are significantly impacted by ethanol. The gasoline tank, intake manifold, carburetor, and fuel injection pump rust as a result of the fuel's corrosive nature. Ethanol also affects non-metallic parts.

According to Fenget et al. (2013), ethanol production requires more land and water resources than methanol synthesis, which produces the hazardous chemical formaldehyde when it burns in an engine. Butanol has the potential to replace or supplement

gasoline as a next-generation biofuel. The industrial solvent butanol can also be made from renewable resources. Butanol can be used as a suitable fuel because it is less corrosive. Butanol is easily transported through pipe lines because of its physical and chemical characteristics.

Gravels *et al*. (2013) indicated that lower molecular mass alcohol such as ethanol and methanol

used as a fuel extenders by blending with gasoline while higher molecular mass alcohol such as

propanol, butanol and pentanol can be used as an additive in alcohols gasoline blends. Because there are more oxygen molecules available in blends of higher-lower molecular mass alcohol/gasoline fuel, the resistance to knock is stronger than in plain gasoline. This also improves compression ratio.

Szulczyk (2013) discussed the differences between butanol and ethanol as a more effective transportation fuel. According to the findings, butanol is a far better fuel than ethanol. Because butanol contains more energy and because gasoline engines do not need to be modified, butanol-gasoline blends do not separate in the presence of water. It is possible to successfully blend butanol with gasoline, and spark ignition engines can operate effectively with up to 100 percent butanol. Because butanol production does not require as much technological investment, infrastructure now used for ethanol production might be converted to butanol production.

Zhang *et al.* (2015) mentioned that butanol can be blended with gasoline and diesel. Butanol has a larger energy density than ethanol, is less corrosive, has a lower vapour pressure, and has a very low solubility in water. These are its key advantages over ethanol. On a life cycle basis, butanol may save 39–56 percent of fossil energy and reduce greenhouse gas emissions by up to 48 percent when compared to gasoline.

According to Churnedet al. (2008), the use of the proper additives with gasoline can improve both the fuel's quality and its combustion/burning properties. Without altering the construction of the engine or employing new equipment, adding an additive to gasoline also helps the engine run more efficiently and reduce exhaust emissions.

Singh *et al.* (2015) indicated that butanol blending with gasoline is suitable due to its physical properties. Butanol works well when combined with ethanol and can enhance the blending of ethanol and gasoline in any ratio. Because butanol has a longer hydrocarbon chain than ethanol, its properties are more closer to those of gasoline than ethanol. Gasoline burned for a shorter period of time than butanol-gasoline mixtures.

Sheridan*et al.* (2015) mentioned in the review article that methanol and ethanol comes under the category of lower molecular weight alcohols and from past it has been used as fuel boosters for spark ignition engines by mixing them with gasoline at higher concentration also. Propanol, butanol, and pentane are among the higher molecular weight alcohols that are frequently added to gasoline for spark ignition engines. It was discovered that higher molecular weight alcohol has better water tolerance, can solve phase separation, has lower Reid vapour pressure, and has better control over volatility while lower molecular weight alcohol enhances efficiency. Both types of alcohols contribute to a decrease in CO and UHC emissions from exhaust.

1.1 Biofuels

Biofuels are gaseous or liquid fuels made from biomass resources that are used in transportation, permanent, portable, and other applications instead of, or in addition to, diesel, gasoline, or other fossil fuels. Examples include alcohols (ethanol, methanol, butanol, etc.), biodiesel (liquid animal and plant oils), green diesel, and biogas (methane derived from animal manure and other digested organic Matter).

1.2 Different Biofuels

Although biofuels are a key component in producing clean energy, there is still much research to be done before they are widely

and affordably available. Biofuel can be categorised into the following sorts according to how much energy it produces for various types of systems.

1. First-generation biofuel,
2. second-generation biofuel, and
3. third-generation biofuel are examples.

(i) First-generation biofuel

These are biofuels made from materials like starch, vegetable oil, sugar, and animal fats, among other things. Conventional biofuel is another name for first-generation biofuel. These kinds of biofuel are directly connected to edible biomasses. Alcohols, biodiesel, bioethers, biogas, and other substances are examples of first-generation biofuels.

(ii) Second Generation Biofuel

The biofuels of the second generation are those that can be produced from different types of biomass. Municipal solid waste, agricultural refuse, and timber crops are used to make second generation biofuel. Because they are non-edible and require a specific procedure for fuel extraction, second generation bio fuels are also referred to as advanced bio fuel. Biological hydrogen, biological methanol, wood diesel, mixed alcohols, syngas, etc. are examples of second generation biofuels.

(iii) Third Generation Biofuel

Biofuels from algal biomass are classified as third generation biofuels. In this stream, third generation biofuels are novel. Different kinds of fuel can be produced from this sort of biofuel. Biodiesel, bioethanol, hydrogen from microalgae, and other examples come to mind. Alcohols, one type of biofuel, offer some benefits over gasoline that allow them to be used in place of or in combination with gasoline in spark ignition engines. When a particular amount of gasoline is blended with them, some fuel qualities are improved. Restrictions on blending with gasoline are a fuel property. Without modifying the engine, ethanol can be easily combined with gasoline up to a level of 20%. Any concentration of butanol can be added to gasoline. Oxygenates are another characteristic of fuel. Since gasoline almost entirely lacks oxygen, this results in both incorrect combustion inside the cylinder and the release of hazardous pollutants from the engine's exhaust. While butanol and ethanol both include 21% oxygen and 35% oxygen, respectively, these substances contribute to the decrease of hazardous gas emissions from engine exhaust. Octane rating is still another significant element. The amount of pressure and temperature needed to ignite a fuel-air mixture is measured by the octane rating. High-octane fuels lessen internal combustion engine banging, which in turn lessens premature combustion inside the cylinder. In the presence of water, butanol-gasoline blends do not separate, whereas ethanol-gasoline blends do. Butanol can be shipped through pipeline while ethanol can’t because it could be contaminated with water.

Following this investigation, we are presented with two alternative goals. First, one can look for a fuel that can either completely or partially replace petroleum fuels in the fleet of internal combustion engines that is now in use. Second, altering the engine such that fossil fuel can be completely replaced. The first goal is preferable because it won't increase engine costs and will allow current engines to run for their entire useful lives. The second goal is the next stage, which is to comprehend how blends behave on an existing engine to determine whether engine modification is necessary or not. Understanding the effect of higher-lower molecular alcohol blends with gasoline on the current fleet of internal combustion engines is another primary goal of this work.

CHAPTER 2

LITERATURE REVIEW

Alternative fuels demonstrate excellent compatibility and dependability with gasoline-fired engines. Both the performance and the amount of air pollution coming from the spark ignition engine's exhaust pipe are improved by it. This section examines the contributions made by academics in the field of spark ignition engines' alternative fuels.

2.1 General Effets of Alcohol with Gasoline:

Agarwal et al. (2014) on testing methanol/gasoline blends in a four cylinder engine found that with the use of methanol substituted gasoline blends, BTE, NO and CO emissions improved, with slight irregularities in HC emissions.

Liu et al. (2007)conducted emission tests on a three-cylinder SI engine fuelled with methanol/gasoline blends and observed that a greater reduction in CO and HC emission when engine was equipped with three way catalytic convertor than without it. also observed that start of combustion advanced and BTE increased, with increase in methanol contentin the blends.

Schifter et al.(2011)tested for the constant mass fuel rate using ethanol blends and witnessed a reduction in HC and CO emissions but an increase in NOxemissions.k was also examined and value seems to be less than unity for all the ethanol blends. The maximum pressure and the total burn-out angle have increased for all the ethanol-blends. Zhang et al. (2015) in their study found that E85 blend showed highest in-cylinder pressure where as B85 blend exhibited lowest in-cylinder pressure.

Dernotte et al.(2010)investigated the use of n-butanol/gasoline blends (B0,B20, B40, B60 and B80) with variation in equivalence ratio and engine load. They observed that at stoichiometric mixture, B0 (0% n-butanol), B20 (20% n-butanol + 80% gasoline), B40 (40% nbutanol + 60% gasoline) emitted similar HC emissions but B60 (60% n-butanol + 40% gasoline) and B80 (80% n-butanol + 20% gasoline) emitted 18% and 47%, respectively, higher HC emissions than gasoline. When the variation of HC emission with load was observed, all the blends showed a reduction in HC emissions. Allbutanol blends emitted higher CO emissions than gasoline. Difference in the NOx emission values among all butanol blends (except 80% blend) and gasoline decreased with increase in equivalence ratio. B80 emitted lower NOx emission at all equivalence ratios.Yusri et al.(2016) tested 5, 10 and 15% blended of 2-butanol/gasoline blends in a Mitsubishi 4-cylinder engine and found that with increase in 2-butanol content in the blends,

NOx, CO and HC emissions reduced whereas CO2 emission increased.

Galloni et al. (2016) tested 20% and 40% butanol blends with variation of k in a 4-cylinder port fuel injected engine. They observed a maximum overall brake efficiency of all blends at k = 1. HC and CO emissions decreased and CO2 emission increased with increases in k, whereas NOx emissions increased and peaked at k = 1.05 and decreased thereafter.

Feng at al.(2015)observed a decrease in engine power and torque when the engine was fuelled with butanol blends, without any change in ignition timing. Engine fuelled with Bu35 at optimized ignition timing emitted lesser HC and CO emissions and more NOx emissions than at un-optimized ignition timing. Similarly CO emissions were found to be lesser, with Bu30 + optimized ignition timing, than Bu30 without optimized ignition timing. Li et al.(2016) studied the combustion, performance and emission characteristics of a SI engine fuelled with isopropanol – n-butanol – ethanol (IBE)and gasoline blends. It was found that IBE30 blend produced good results, in terms of performance and emission characteristics. IBE30 blend also emitted lower HC, CO &NOx emissions and higher BTE than gasoline.

Acetone, Butanol, and Ethanol (ABE) mixes were evaluated against gasoline and among each other at various vol. percent ratios by Nithyanandanet al. (2016). They discovered that the mixture with a high acetone content released less HC than gas. They proposed employing a blend with a high acetone content and noted no significant changes in NOx emissions.

Diisopropyl ether is a new alternative fuel that has been explored by Dhamodaran et al. (2016). They discovered that using its

gasoline blends can lower CO and HC emissions while slightly increasing BTE. Additionally, they saw increased in-cylinder pressures while using gasoline/diisopropyl ether mixtures..

2.2 Use of Alternative Fuel other than Alcohol in SI Engine:

Murillo et al.(2005) two different multi-cylinder spark ignition outboard engines' pollution and performance parameters were experimentally reported. In comparison to gasoline, they discovered that employing LPG resulted in lower specific fuel consumption and power production. Utilizing LPG as a fuel reduces CO emissions but increases HC and NOx emissions when it comes to exhaust emissions.

Yousufuddin and Mehdi (2008) experimentally investigated the performance and emission characteristics of variable compression SI engine fuelled on LPG. The experimental findings indicated that using LPG increased specific fuel consumption and lowered engine volumetric and thermal efficiency in comparison to gasoline. Compared to gasoline, there was an increase in CO and HC exhaust emission.

Lee et al.(2009) investigated the performance and emission characteristics of 2.7L spark ignition engine on LPG fuelled with Di methyl ether (DME) blends. In this investigation, three distinct mixtures of DME and LPG in volumes of 10, 20, and 30% DME were created. According to the findings, engine torque reduced as DME content increased while bsfc increased in comparison to LPG. Compared to LPG, the temperature of the exhaust gas increased for the blends. Compared to gasoline, the addition of DME content increased the engine's propensity for banging. Compared to LPG, HC and NOx exhaust emission increased at low engine speed.

Anish Raman et al.(2014) experimentally found the behaviour of methyl tetrabutyl ether on multi cylinder, MPFI spark ignition engine on varying engine speed. Methyl tetrabutyl ether is added to gasoline to increase the thermal efficiency of the brakes and the amount of brake-specific fuel used. Compared to gasoline, the emissions of CO and HC were lower but CO2 and NOx were higher for methyl tetrabutyl ether-gasoline blends.

By adjusting the ignition time, **Erkuş et al. (2015)** tested an LPG-fueled, 1.4-L multi-cylinder SI engine without a catalytic converter. It has been demonstrated that using LPG to advance ignition time increases brake power and thermal efficiency. The amount of NOx emissions rose when the ignition timing was advanced, however the impact on CO emissions was minimal when using LPG fuel. As LPG fuelled ignition timing advances, HC emission increases.

Elfasakhany(2016) reported the behaviour of acetone-gasoline blends on the performance and emission analysis of a single cylinder 4-stroke spark ignition engine. The outcome showed that the engine's torque, power, volumetric efficiency, in-cylinder pressure, and exhaust gas temperature increased as the amount of acetone in the mixture increased. Acetone and gasoline fuel blends are more successful in reducing emissions under high-speed situations than under low-speed conditions. In compared to gasoline, acetone-gasoline blends reduced CO, CO2 and UBHC emission by 43, 32, and 33%, respectively.

2.3 Use of Additives in Alcohol -Gasoline Blends Fuel in SI Engine:

Srinivasan and Saravanan (2010) studied the results of adding cycloheptanol to ethanol-gasoline blend fuel in multi-cylinder SI engines. The findings demonstrated that utilising an additive increases brake thermal efficiency when ethanol-gasoline blends are used instead of regular gasoline. When compared to gasoline, the exhaust emissions of CO, CO2, and NOx are significantly reduced but those of HC and O2 are enhanced when oxygenated additives are used.

Balaji*et al.* (2010) conducted the engine test on a single cylinder, 4-stroke gasoline engine by blending ethanol and isobutanol with gasoline. Engine performance and exhaust emissions are improved when ethanol and ethanol-isobutanol are used as fuel additives to unleaded gasoline. The addition of ethanol or ethanol-isobutanol to gasoline raises the volumetric efficiency, thermal efficiency, and fuel consumption of the brakes, respectively. However, adding 5% isobutanol and 10% ethanol to gasoline raises mean average values by 6.2, 8.2, 7.8, and 6.7 percent, respectively. Additionally, the mean average value of the fuel consumption

for brakes falls by around 3.4%. The addition of 10 percent ethanol and 7.5 percentisobutanol to the unleaded gasoline is achieved without any problems during engine operation.

Feng*et al.* (2013) experimentally studied the effect of addition of H2O in butanolgasoline blended fuel in a single cylinder, 2-valve, four-stroke, air cooling, spark ignition motorcycle engine. The result revealed that addition of H2O to butanol-gasoline blends increased brake specific energy consumption and engine torque. Exhaust emission of CO and HC decreased while emission of NOxand CO2 increased in comparison to gasoline.

Attalla *et al.* (2013) experimentally investigated the effect of using acetic acid –ethanol-gasoline blended fuel on 2-stroke, single cylinder spark ignition engine. According to the findings, using blended fuel like G70/A15/E15 increases engine torque and brake power. When the amount of ethanol and acetic acid was higher than pure gasoline fuel, it was discovered that the exhaust emission of hydrocarbon and carbon monoxide was reduced.

Zhang *et al.* (2015) reported the comparative study amongst ethanol-gasoline blends, butanol-gasoline blends and acetone-butanol-ethanol blends on V8 spark ignition engine. The results showed that although B85 has the lowest peak pressure and most retarded combustion phasing, E85 has the highest peak in-cylinder pressure and most advanced combustion phasing. Because butanol has the lowest vapour pressure and hence produces relatively poor evaporation, B85 has the longest ignition delay, whereas ABE 85 falls between E85 and B85. Under stoichiometric conditions, the thermal efficiency of the brakes is lower for all three fuels and higher. Compared to E85, ABE85, and gasoline, B85 has higher HC and CO emissions, whereas E85, ABE85, and B85 have lower emissions than gasoline.

Elfasakhany (2016) experimentally investigated the performance and emission characteristics of single cylinder, 4-stroke spark-ignition engine in between the range (2600-3400 rpm with an increment of 100 rpm) of the engine speed. In this investigation, gasoline was blended with the dual fuels iso- and n-butanol (1.5, 3.5 and 5 percent by volume). The results showed that compared to gasoline, the inclusion of dual fuel alcohols reduced the volumetric efficiency of the engine. All fuel blends above gasoline were found to have lower exhaust gas temperature and cylinder gas pressure. Gasoline outperformed fuel mixtures in terms of engine power and torque. At all engine speeds, fuel mixes had lower CO and UHC emissions than gasoline. It has been discovered that using fuel blends rather than gasoline reduces CO2 emissions.

2.4 Various Results of Work that shows the dominence of Alcohol with Gasoline*:*

Hseih*et al.* (2002) reported that using absolute ethanol and gasoline blended fuel with the volumetric ratios of 0-30 percent (E0, E5, E10, E20 and E30), the same torque values were acquired at various proportions of ethanol- gasoline blends compared with pure gasoline at different throttle openings and engine speeds. An engine with a multi-cylinder, 4-stroke spark ignition underwent performance and emission testing. In contrast to gasoline, the fuel blends were found to produce less CO and HC and more CO2, respectively, in the exhaust. Instead of the amount of ethanol in the blends, NOx emissions are influenced by the engine's operating conditions.

Al-Hasan (2003) did the experiment utilising ethanol/gasoline mixes as fuel in a four-cylinder, four-stroke spark ignition engine. The findings showed that using ethanol-blend gasoline fuel boosted braking power, thermal efficiency, and volumetric efficiency while reducing brake-specific fuel consumption and air-fuel ratio by 2.4 and 3.7 percent, respectively. When ethanol-gasoline blends were compared to gasoline, it was discovered that CO and HC emissions decreased while CO2 emissions rose. Additionally, it was discovered that fuel blends with 20% ethanol (E20) produced the optimum engine performance.

Yüksel and Yüksel (2004) investigated the effect of gasoline (E0) and gasoline-ethanol blends on the performance of four stroke, multi-cylinder, water cooled, carburetted spark ignition engine. For the investigation, they created a new carburetor. They discovered that the blend fuel increased particular fuel consumption while reducing engine torque and power output readings. In comparison to gasoline, the engine's thermal efficiency showed no discernible difference. The CO and HC emissions were

decreased while the CO2 emissions were enhanced by the usage of ethanol-gasoline blended fuel.

Yamin*et al*. (2005) studied the impact of adding methanol to low-octane gasoline on single-cylinder spark ignition engines, four-stroke engines, and engines with varied compression ratios. The volume fraction of methanol in gasoline ranged from 5 to 25 percent. The characteristics of the blends and an analysis of the engine's performance were assessed in this investigation. The results showed that as the percentage of methanol in the blends grew relative to the gasoline, the calorific value decreased while the octane number climbed. Increased percentages of methanol in the blends over gasoline were shown to boost brake power and brake thermal efficiency.

Yücesu*et al*. (2006) investigated the effect of ethanol-gasoline blends on performance and emissions of a single cylinder 4-stroke variable compression ration spark ignition engine. They claimed that at 2000 rpm, engine torque improved with gasoline fuel as compression ratio climbed up to 11:1. The increase in engine torque above the 8:1 compression ratio was roughly 8%. At the higher compression ratios, the torque output did not alter significantly. With a 13:1 compression ratio, the maximum increase in engine torque was achieved for both E40 and E60 fuels. As the amount of ethanol in the fuel blend increases, the temperature of the exhaust gas and the emissions of HC and CO tend to decrease.

Celik (2008) experimentally investigated the performance and emissionscharacteristics of a single–cylinder four-stroke gasoline engine on ethanol-gasoline blend at high compression ratio. Results showed that power somewhat increases along with the amount of ethanol in the blend gasoline. E25, E50, and E75 fuels, respectively, result in power improvements of 3, 6%, 2%, and 1% when compared to pure gasoline fuel. When the ethanol percentage is increased to greater beyond 50%, power increases begin to slow down. It was discovered that there were less CO, CO2, HC, and NOx emissions.

Yanju*et al.* (2008) reported the effect of methanol/gasoline blends on performance and emission characteristics on a multi-cylinder MPFI, four-stroke spark ignition engine. For the investigation, three methanol-gasoline blends containing 10, 20, and 85% methanol were used. The outcome demonstrated that the methanol injection increased brake thermal efficiency while decreasing ignition delay and combustion length. The decrease of CO and NOx emissions is facilitated by the addition of methanol fraction to gasoline.

Koç*et al.* (2009) experimentally investigated the performance and exhaust emissionof a single cylinder, 4-stroke gasoline engine on ethanol-gasoline blends. The results showed that, given the amount of ethanol in the mix, the reduced energy content of ethanol-gasoline fuel resulted in a small increase in the engine's brake-specific fuel consumption. The torque of blended fuels (E50 and E85) was found to be higher than that of base gasoline (E0) in all speed ranges as a result of higher latent heat of vaporisation, ethanol addition, and oxygenated fuel. The results indicated that adding ethanol to gasoline enhanced engine torque, power fuel consumption, and compression ratio while decreasing CO, HC, and NOx exhaust emissions.

Costa and Sodré (2010) experimentally investigated the performance and emission characteristics of a 1.0-L, eight-valve, four-cylinder, production SI engine on hydrous ethanol and ethanol-gasoline blended fuel on varying the speed in the range from 6000 to 2500 rpm. At all engine speeds, the results showed that hydrous ethanol produced higher thermal efficiency and bsfc than the ethanol-gasoline mixes. In comparison to a gasoline-ethanol blend, hydrous ethanol increased CO2 and NOx emissions while decreasing CO and HC emissions in terms of exhaust emissions.

A four-cylinder, four-stroke, multi-point injection system spark ignition engine's performance and combustion characteristics were examined by **Eyidoganet al. (2010)** in relation to alcohol-gasoline fuel mixtures. For the investigation, ethanol and methanol were chosen as the two alcohol types. With gasoline, the concentration of both alcohols ranged from 5 to 10%. The outcome demonstrated that, in comparison to gasoline, the bsfc rose for all fuel mixtures. For alcohol-gasoline mixtures, cylinder gas pressure began to climb, and the gasoline had the lowest rate of heat release.

Szwaja*et al.* (2010) investigated the combustion characteristics of 20, 30 and 100 percent n-butanol and their blends with

gasoline by analysing in-cylinder pressure data and fraction profiles of mass burn over a range of spark timings, compression ratios and engine loads. For the analysis, a single cylinder, four-stroke CFR spark ignition with variable compression ratio was used. The length of combustion for n-butanol was comparable to that of regular gasoline. The timing of the spark plugs for gasoline had to be delayed in relation to the timing for the maximum brake torque (MBT). It was discovered that the combustion knock behaviour of n-butanol and gasoline is remarkably similar.

Chen *et al.* (2011) experimentally investigated the behaviour of ethanol-gasoline blends on cold start emissions of a 4-cylinder in-line, multi-port gasoline injection 4-stroke spark ignition engine. The ethanol volume added to the gasoline ranged from 5, 10, 20, 30, and 40% to create the mixed fuel. The results showed that adding additional ethanol to gasoline made the air/fuel mixture leaner and had an impact on the blends' Reid vapour pressure. Up to E30, the engine started reliably, but around E40, the lean air/fuel ratio makes things worse. In comparison to gasoline, the amount of carbon monoxide and hydrocarbon emissions dramatically decreased when ethanol was added.

Costa and Sodré (2011) tested the performance of a 1.0-L, eight-valve, fourcylinder, spark ignition engine on hydrous ethanol and anhydrous ethanol at variable compression ratio. The study employed three compression ratios: 10:1, 11:1, and 12:1. Increased compression ratios at high speeds improve engine torque, BMEP, and output power for both hydrous and anhydrous ethanol. Specific fuel consumption fell as compression ratio rose, but hydrous ethanol brake thermal efficiency and exhaust gas temperature rose. Hydrous ethanol's volumetric efficiency fell at low compression ratios. Additionally, it was discovered that the usage of hydrous ethanol raised CO2 and NOx levels while decreasing CO and HC emission.

Yang *et al.* (2011) reported the performance of a single cylinder 4-stroke carburetted spark ignition engine fueled with gasoline-butanol blends of different mixing fractions. For the investigation, two mixtures of butanol at 30 and 35 percent by volume of gasoline were used. It was demonstrated that butanol is a highly encouraging alternative fuel with significant potential for energy savings; a decrease in the energy consumption and emissions unique to brakes was noted. In comparison to gasoline, it was discovered that NOx emissions increased while CO and HC exhaust emissions decreased.

Pandya*et al.* (2011) experimentally investigated the performance of 2-stroke gasoline engine on three different alcohols viz. gasoline is blended with n-butanol, ethanol, and methanol. The results showed that adding various alcohols to gasoline increased engine mechanical efficiency, fuel consumption, braking power, and thermal efficiency of the brakes. With regard to engine torque, adding 5% methanol, 5% ethanol, and 5% n-butanol to gasoline produced the greatest results for all parameters.

Karavalakis*et al.* (2012) investigated the impact of ethanol fuel on emission of various model of gasoline engine. The models used for this study ranged in year from 1984 to 2007, with one of them being a flexible fuel vehicle (FFV). The findings indicated that whereas CO and NOx emissions increased in the older vehicle fleet, THC/MNHC emissions decreased. In the fleet of newer vehicles, NOx pollution was decreased while CO emission did not change, and fuel economy decreased as ethanol percentage increased. When compared to the previous fleet of vehicles, harmful emissions were reduced as ethanol content rose.

Merola*et al.* (2012) indicated the effect on the combustion process of n-butanol blended in volume with pure gasoline in a spark ignition engine. They used a single-cylinder PFI SI engine operating at low speed, modest boosting, and wide-open throttle to conduct their investigation. They discovered that butanol blends up to 40% concede working in advanced spark timing without manifesting any detrimental consequences on engine performance.

Melo*et al.* (2012) experimentally investigated the combustion and emission characteristics of hydrous ethanol-gasoline blends on a 1.4 L, 4-inline cylinder FIAT Flexfuel spark ignition engine. The findings showed that ethanol blends increased particular fuel usage when compared to gasoline. A rise in energy efficiency was seen. Compared to gasoline, blends have lower CO2 emissions but higher CO3 emissions. The mixes' NOx emissions displayed complex behaviour.

Farkade*et al.* (2012) experimentally investigated and compared the performance and emission characteristics of methanol,

ethanol and butanol blends with gasoline in a single cylinder 4-stroke spark ignition engine. Alcohol content in the gasoline used for the study ranged from 0 to 30 percent. Among the studied fuel, M10, E10, and B20 exhibit better results within the same alcohol blend group. They discovered that butanol blends with an oxygen content of roughly 5% have higher thermal efficiency than blends with higher levels of oxygen. It was discovered that butanol's performance at a 20 percent blend provides greater fuel replacement with better thermal efficiency without requiring any modifications. Additionally, butanol at a 20 percent blend shows least brake-specific fuel consumption, while ethanol at a 10 percent blend shows least. All alcohol blends had lower CO and HC emissions than regular gasoline, but the M30 blend had the lowest emissions overall.

Gu*et al.* (2012) investigated the effect of gasoline-n-butanol blends in combination with EGR in a port-fuel injection spark ignition engine and they found that the brake specific fuel consumptions of Bu10, Bu30, Bu40 and Bu100 are higher than that of Bu0. Because n-butanol has a poor heating value, Bu100's blend had a higher fuel usage than other blends. The maximum brake torque timing (MBT) is provided at roughly 25o CA BTDC for all mixes, and the lowest BSFC is presented there as well. In comparison to gasoline, gasoline-n-butanol blends showed lower engine-specific CO, HC, and NOx emissions. Additionally, it was discovered that n-butanol blends had lower particle matter concentrations than gasoline.

Simio*et al.* (2012) The impact of ethanol content on a 1.6-liter, 4-cylinder in-line, spark-ignition engine has been experimentally studied. Up to 85% of the volume of ethanol was blended with gasoline. It was discovered that the engine's thermal efficiency rose as the ethanol content increased. Increases in ethanol content were found to lower emissions of nitrogen oxides, while improvements in thermal efficiency also reduced emissions of carbon dioxide.

Irimescu (2012) experimentally investigated the fuel conversion efficiency and performance characteristics on iso-butanol-gasoline blends in a passenger car having multi-cylinder 4-stroke port injection spark ignition engine. Gasoline was mixed 50 percent and 100 percent with iso-butanol. The results showed that fuel conversion efficiency fell by 9% at part load and by 11% at full load compared to gasoline. It was discovered that the power produced by the engine running on a 50% isobutanol blend and pure isobutanol was comparable to that of gasoline.

Gravalos*et al.* (2013) experimentally studied the emission characteristics of lowerhigher

molecular mass alcohols (propanol, butanol and pentanol) in a single cylinder, carburetted, four-stroke and air cooled spark ignition engine. In this investigation, unleaded gasoline was blended with five different alcohols, including ethanol, methanol, propanol, butanol, and pentanol. Only the volumetric proportion of ethanol among all the alcohols was variable, ranging from 2 to 22 percent. The results showed that, in compared to plain gasoline, the addition of lower-higher molecular mass alcohols/gasoline fuel blends decreased CO and HC emissions while increasing NO and CO2 emissions.

Canakci*et al.* (2013) studied the impact of alcohol-gasoline blends on the exhaust emission of a 4-cylinder, 4-stroke and multi port injection spark ignition engine. Methanol and ethanol, two alcohols, were combined with gasoline and tested at two distinct speeds of 80 km/h and 100 km/h. The test results showed that methanol-gasoline and ethanol-gasoline mixes had lower CO, CO2, UHC, and NOx exhaust emissions than gasoline at a speed of 80 km/h. For methanol-gasoline blends, especially at M10, emissions of CO2 and NOx rose at speeds of 100 km/h. Additionally, it was discovered that when methanol and ethanol rates in the fuel grew relative to gasoline, so did the proportion of air/fuel comparability.

Costagliola*et al.* (2013) experimentally investigated the influence of ethanolgasoline blends and n-butanol-gasoline on exhaust emission and combustion efficiency of a conventional 1.6 L port injection SI engine. The experimental findings showed that E85 had a somewhat higher combustion efficiency than gasoline. Compared to gasoline, employing alcohol/gasoline blends lowered regulated emissions. E85 blends were shown to have the greatest reduction in CO, NOx, and THC when compared to regular gasoline. Blends of alcohol and gasoline were found to have lower particle counts than pure gasoline. Alcohol/gasoline mixtures were more effective than gasoline at reducing unregulated emissions.

Siddegowda*et al*. (2013) explored how a multi-cylinder, MPFI, spark ignition engine would perform with gasoline (E0) and gasoline-ethanol mixtures. The findings indicate that adding 20 percent ethanol to gasoline increases brake thermal efficiency while somewhat reducing fuel consumption. Leaning effect was observed to reduce CO and HC emissions while increasing CO2 emissions as compared to gasoline.

Mittal *et al.* (2013) investigated the performance and emission characteristics of a single cylinder 4-stroke spark ignition engine on butanol blend containing 10 and 15 percent by volume with gasoline. They claimed that when powered by gasoline, B10, and B15, the ceramic coated engine's peak cylinder pressure is higher than that of the base engine. SFC is higher when fueled with B10 in basic engine compared to gasoline in base engine by 1.48 percent and 0.94 percent at lower and maximum loads, respectively. At 85 percent of the maximum load, B10 fuel blend showed a maximum increase in brake thermal efficiency of 3.2 percent in the base engine and 7.4 percent in the ceramic coated engine when compared to gasoline in the base engine. The exhaust temperature increased in the ceramic coated engine when both B10 and B15 fuel were used.

Deng *et al.* (2013) investigated the effect of butanol addition with gasoline on ignition and valve timing of a single cylinder 4-stroke spark ignition engine. The findings showed that butanol addition (35 percent mix) allowed ignition timing to be advanced without knocking for increased combustion efficiency, which improved engine performance in terms of power, fuel consumption, and HC and CO emissions, but at the expense of NOx emissions.

Türköz*et al.* (2014) researched the ideal ignition timings for an E85-fueled 4-stroke, 4-cylinder SI engine. The results showed that torque increased and then power output increased relative to the reference fuel at advanced ignition timing up to 4o. While changing the timing of the ignition had no discernible effect on CO and CO2 emissions, delaying the ignition increased HC emissions and fuel consumption due to inefficient combustion.

Bokhary*et al.* (2014) experimentally studied the behaviour of ethanol-unleaded gasoline blends on single cylinder, 4-stroke spark- ignition engine performance and emissions. The blends' maximum ethanol content ranged from 5 to 15 percent. The results showed that, in comparison to unleaded gasoline, ethanol-unleaded gasoline blended fuel increased thermal efficiency, braking torque, brake power, brake mean effective pressure, and volumetric efficiency. Comparing the blended fuel to unleaded gasoline, CO and CO2 exhaust emissions dropped but NO and O2 concentrations rose.

Pal (2014) experimentally investigated the performance and emission characteristics of an MPFI, 4 cylinder spark-ignition engine with different ethanol-gasoline fuel blends. With gasoline, the ethanol content ranged from 5 to 15%. The results showed that adding ethanol to gasoline slightly improved braking power and thermal efficiency while just slightly raising brake-specific fuel consumption. Ethanol and gasoline are blended to lower CO, HC, and NOx emissions when compared to pure gasoline.

Varol*et al.* (2014) experimentally investigated effect of methanol, ethanol and n-butanol blends with gasoline on exhaust emission of a four cylinder, four stroke, spark ignition engine. The findings showed that unleaded gasoline has a lower bsfc than M10, E10, and B10. In comparison to a blend of ethanol or butanol with unleaded gasoline, the fuel consumption for blended fuels including methanol also shows a little rise. The BTE rises as engine speed rises; for E10 and M10, it was on average 4.5–6.8% lower than unleaded gasoline, while for B10, it was on average 2.8 percent lower.

Elfasakhany (2014) experimentally studied the behaviour of n-butanol-gasoline on a single cylinder spark ignition engine. Using n-butanol blends instead of gasoline decreased engine performance. When compared to gasoline, the exhaust gas temperature for the mixes was found to be lower. When compared to gasoline, CO, UHC, and CO2 emissions were determined to be substantially lower. When compared to gasoline, CO, UHC, and CO2 emissions were reduced at relatively low engine speeds, while at high engine speeds, the difference in emission reduction was less than gasoline.

Gong et al.(2014) experimentally studied the effect of iso-propanol /gasoline blends on exhaust emission of a three cylinder, port -injection spark ignition engine combined with exhaust gas re-circulation. The use of exhaust gas recirculation rate lowered NOx

emissions with an increase in blending ratio, according to the results of the exhaust emission tests. As the rate of exhaust gas recirculation increased, HC and CO emissions rose. As load and exhaust gas recirculation rate rose, the concentration of particulate matter also increased monotonically.

Ravitej*a et al.* (2015) investigated the effect of hydrogen enrichment on butanol blended gasoline in a single cylinder 4-stroke EFI spark ignition engine operating at a stoichiometriccondition. With gasoline, butanol volume percentages of 10, 20, 30, and 100% were used, and two hydrogen concentrations of 5% and 10% were also taken into account for the investigation. The findings indicated that, in an unaltered engine, a fuel mixture containing 30% butanol is preferable to pure gasoline. Fuel consumption, which is higher for butanol blends than pure gasoline, is decreased by hydrogen enrichment. Blends with a 10% hydrogen enrichment lowered HC and CO emissions while increasing NO emissions.

Elfasakhany (2015) studied the performance and exhaust emissions from a single cylinder, 4-stroke and air cooled spark ignition engine on methanol-ethanol-gasoline blends. The torque and volumetric efficiency of methanol gasoline blends are higher than those of ethanol gasoline blends, while the brake power and torque of methanol-ethanol-gasoline blends are more moderate. Gasoline exhibits the lowest torque, brake power, and volumetric efficiency among all fuel blends. In comparison to gasoline, methanol-ethanol gasoline exhibits lower CO and UHC emissions. Methanol-gasoline blends showed lower CO and UHC emission than all other fuel blends. Blends of ethanol and gasoline have average exhaust emissions.

Singh *et al.* (2015) experimentally investigated the butanol-gasoline blends performance and emission characteristics on a four cylinder, water cooled, MPFI, medium duty spark ignition. They claimed that while the combustion properties of the B5, B10, and B20 blends were comparable to gasoline, butanol-gasoline blends had a slightly higher BSFC than gasoline. While the BTE of butanol-gasoline blends was lower than that of gasoline, the heat release for gasoline starts considerably early than that for butanol-gasoline blends. Blends of butanol and gasoline had lower EGT than regular gasoline. Butanol-gasoline mixtures produced less smoke and BSNO and BSCO emissions. At higher engine speeds, BSHC emissions for B5 and B10 were comparable. At all engine speeds, B50 and B75 exhibit lower BSHC compared to gasoline.

Sharudin*et al*. (2015) summarized that lower molecular weight alcohols have low polluting properties and high efficiency through their lean operating ability. Better water resistance, volatility control, phase separation resolution, and lower Reid vapour pressure of the blends are all benefits of the greater molecular weight alcohols. Due to the oxygen present, which aids in incomplete combustion, both lower and greater molecular weight alcohol will produce fewer emissions of CO and UHC.

Tewari (2015) experimentally investigated the performance characteristics of a multi-cylinder, MPFI, 4-stroke gasoline engine on ethanol-gasoline blends. The experiment's findings demonstrated that adding ethanol to gasoline increased the engine's brake thermal efficiency and braking power, though bsfc was discovered to be on the higher side. While NOx emissions were on the higher side for ethanol-gasoline mixes, CO and HC emissions were reduced.

Mack *et al.* (2016) investigated the butanol isomer combustion in multi cylinder, four stroke homogeneous charge compression ignition (HCCI) engines. In this study, n-butanol and isobutanol, two isomers of butanol, were tested as fuel and then contrasted with ethanol and gasoline. The results of the tests revealed that both isomers exhibit single stage ignition behaviour that is combustion stable. N-butanol is used in engines because it is more stable under all circumstances and because, at the start of combustion, it releases heat more quickly than gasoline. In comparison to isobutanol and the other tested fuels, n-butanol was shown to have a reduced knock resistance. With other studied fuels, both butanol isomers displayed identical exhaust emission ranges.

2.5 Conclusion from Literature Review:

From the literature review we have observed that in the previous years studies done on the Performance Characteristics Of A Multi Cylinder MPFI Spark Ignition Engine. Finally it can be cocluded that by the use of Ethanol–Petrol Blended Fuels,

hydrogen –petrol blends, We can maximize the torque or power at a specific loading condition and pollutents can be minimized. Further researches are on going in the given area.

2.6 Objective of Present Study:

This topic of study is in research phase and further studies are on going so we opted this topic for our project and our main objective is to improve performance and emission characertisics of multi cylinder MPFI SI engine using petrol-ethenol blend in different ratios.(e.g. e10,e20 etc.).

CHAPTER 3

EXPERIMENTAL SETUP& METHODOLOGY

3.1Experimental setup:

The setup consists of a four cylinder, four stroke, Multi Cylinder (MPFI) SI engine (Detailed specifications listed in Table: 1) connected to eddy current dynamometer for loading. Provisions are made for interfacing airflow, fuel flow, temperatures and load measurement. The set up consists of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. A Petrol tank was used to supply petrol in the inlet manifold of the engine. To use ethenol, another tank was provide.Table 4 displays the technical specifications of the measurement apparatus, and Figure 1 displays the schematic representation of the experimental setup.

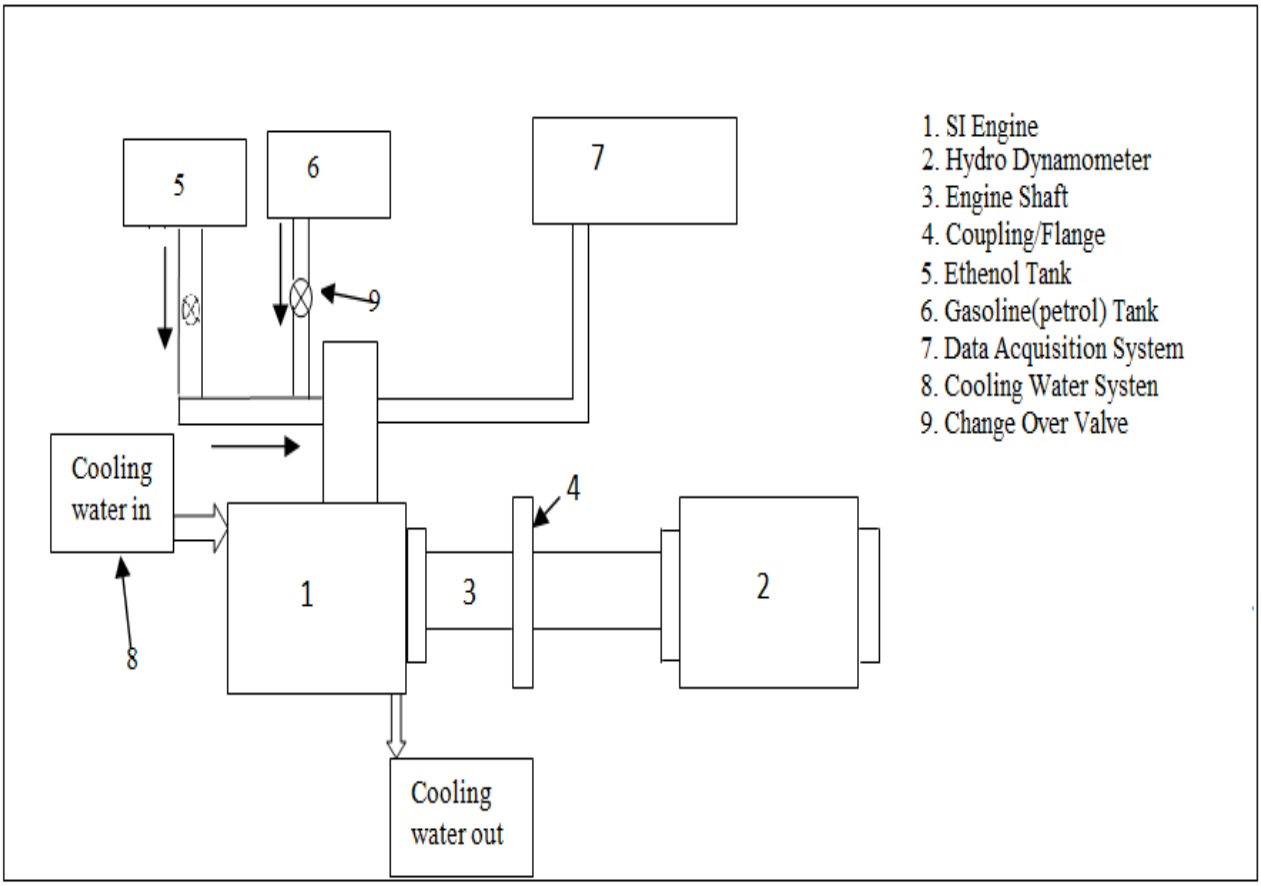

Fig.3.1 Schematic Diagram of the Experimental Setup

Table-1: Technical specifications of test engine

Characteristics	Value
Type of engine	4 E-FE DOHC 16V
Make	Maruti Wagon R
Volume V, cm3	1332
Compression ratio ε	9,8
Max. Pe, kW	65
Torque Ms, Nm	124
Fuel	Gasoline/Ethenol
Ignition system distributor	TCCS – II, Toyo Denso

3.2 Methodology:

The engine's external load was gradually increased while the rack was set to its full load position, which changed the engine's speed and torque. First, straight gasoline was used to run the engine, and then its mixtures. The engine was allowed to run for long enough to burn through the remaining fuel from the previous test before starting with a new fuel mixture. The full sample of fuel was examined using the same method. Throughout the experiment, measurements of the various fuels' engine speed, torque, fuel consumption, exhaust emission values, and combustion parameter values were taken. Using common equations, it was possible to determine metrics like brake power, brake-specific fuel consumption, brake thermal efficiency, and brake mean effective pressure.

3.3 Materials:

Petrol purchased from a nearby gasoline station in Ghaziabad, Uttar Pradesh, India, was utilised as the fuel for this test. Blends of the produced bioethanol with gasoline in various ratios; bioethanol manufactured from diverse Nigerian feedstocks using fermentation and distillation procedures. Based on the recommendations made in earlier studies, the fuel blend ratios utilised in the trials were chosen. Table 2 provides the mixing percentages.

According to American Society for Testing and Materials (ASTM) guidelines, gasoline, ethanol, and their mixtures were described. Table 3 lists the attributes as reported by Nwufo et al. (2013).

Table 2 Composition of bioethanol/petrol blended sample used

Sample code	% Ethanol	% Petrol
E10	10	90
E20	20	80
E30	30	70
E40	40	60
E50	50	50

Table 3 Properties of Bioethanol Fuel Blended with Petrol

Properties	Petrol	E10	E20	E30	E40	E60	Bioethanol
Density(kg/m^3)	747.7	750.8	760.5	778.2	779.2	781.2	789.0
Vapour Pressure (kpa)	36	39	39	38	35.6	31	9.5
Flash Point(^{0}C)	-65.0	-40.0	-20.0	-15.0	-13.5	-1.0	12.5
Heating Value (MJ/kg)	44.4	44.22	42.08	40.48	38.50	35.84	29.78
Auto-Ignition Temperature (K)	519	533	552	552	567	618	638

In order to guarantee homogeneity and avoid phase separation, the blends were well mixed in a mixer just before the experiments. A multi-cylinder, four-stroke engine connected to a hydraulic dynamometer underwent test runs.

3.4 Experimental procedure:

At the initial stage, various engine loads were used for the experiments. The tests were carried out while keeping a constant load at six different speeds: 2000, 2500, 3000, 3500, 4000, and 4500 rpm. An hydro dynamometer, by which load is applied, is connected to the engine. The injection timing was regulated at 23° BTDC, and the compression ratio was 18.0. The engine was given a 15-minute warm-up period before each test to achieve balance. Monitoring the temperatures of the coolant and exhaust allowed for this conclusion. Engine speed, brake power, fuel consumption, BSFC, BSEC, exhaust gas temperature, pollutants, and smoke density were among the parameters that were assessed during the tests.

3.5 Formulation used for calculation of various parameters are described below:

Density (kg/m3) times volume (m3) equals Mf. / time
Load (N) * Arm Length = Torque (Nm) (m)
Braking power (kW) is calculated as (2*speed*torque) / (60*1000).
Brake Thermal Efficiency (%) = (Brake power (kW) *3600*100) / [Fuel flow(kg/h) *Calorific value(kJ/kg)]
Fuel flow (kg/hr) / brake power = brake specific fuel usage (Kg/kWh) (kW)
Calorific value (kJ/kg) x BSFC (kg/kW-h) / 1000 = the brake specific energy consumption (MJ/kWh).

CHAPTER 4

RESULT AND DISCUSSION

4.1Engine performance parameters

4.1.1 Engine torque (Nm):

The change of engine torque across all fuel samples with respect to engine speed is depicted in Fig.4.1. As can be seen, torque rises steadily with speed up to a maximum value before declining as speed rises further. This is a result of the engine's poorer volumetric efficiency and mechanical friction loss at higher engine speeds. Petrol and E20 fuels produced engine torque that was greater than that of other fuel samples. The maximum torque was measured for the various gasoline samples at relatively similar engine speeds, as indicated in the figure below. The lower calorific value of the bioethanol fuel may be the cause of the reduced torque when using ethanol blend fuel.

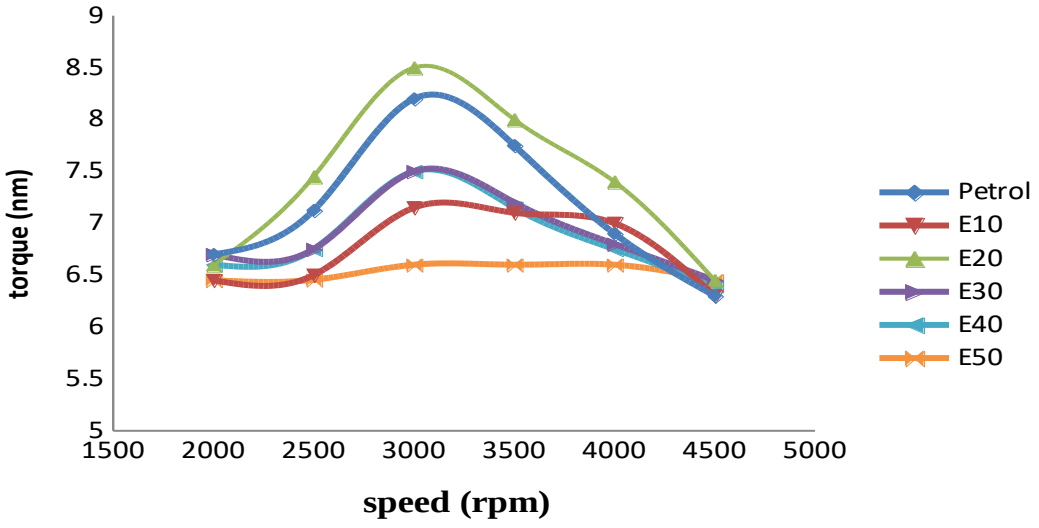

Fig.4.1 Variation of Engine Torque with Engine Speed for Different Fuels

4.1.2 Brake Power (Kw):

Figure 4.2 displays the brake power values for all fuel samples. The engine braking power rose gradually as engine speed increased. At various engine speeds and with various fuel samples, the engine's maximum braking power was measured, and it was found to be 2.5kW, 2.375kW, 2.45kW, 2.4kW, 2.4kW, and 2.2kW at around 4000rpm for gasoline, E10, E20, E30, E40, and E50, respectively. Higher ethanol blends' lower brake power ratings when compared to gasoline can be attributable to their lower calorific values.

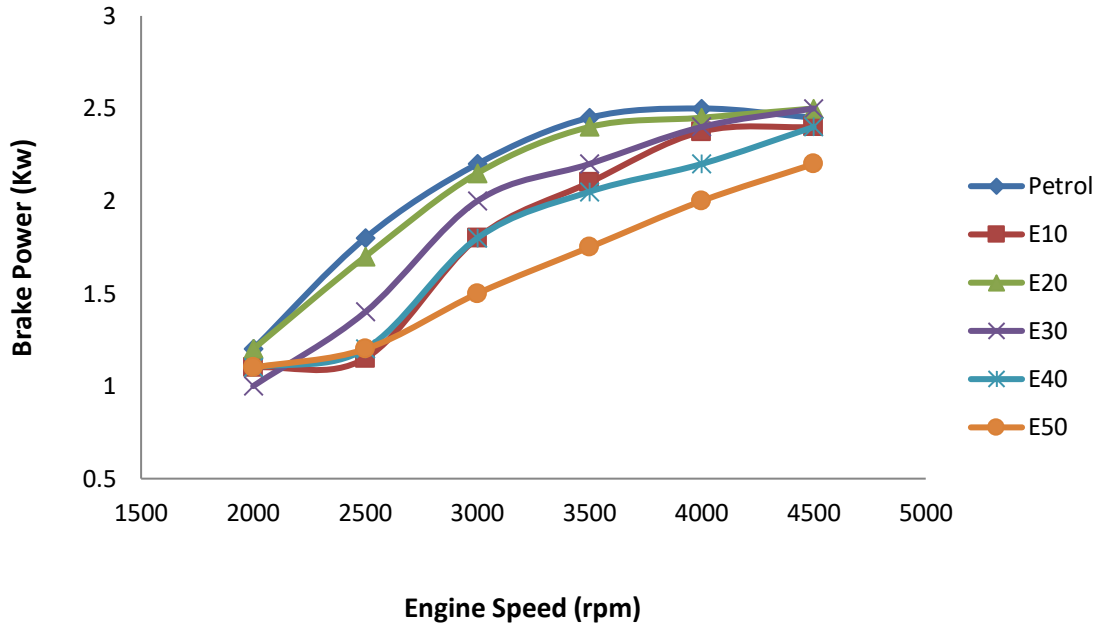

Fig.4.2 Variation of Brake Power with Engine Speed for Different Fuels

4.1.3 BMEP (kpa):

As seen in fig.4.3, there is a strong correlation between BMEP and engine torque. The highest BMEP was produced by gasoline and E20 at a 3000 rpm engine torque speed.

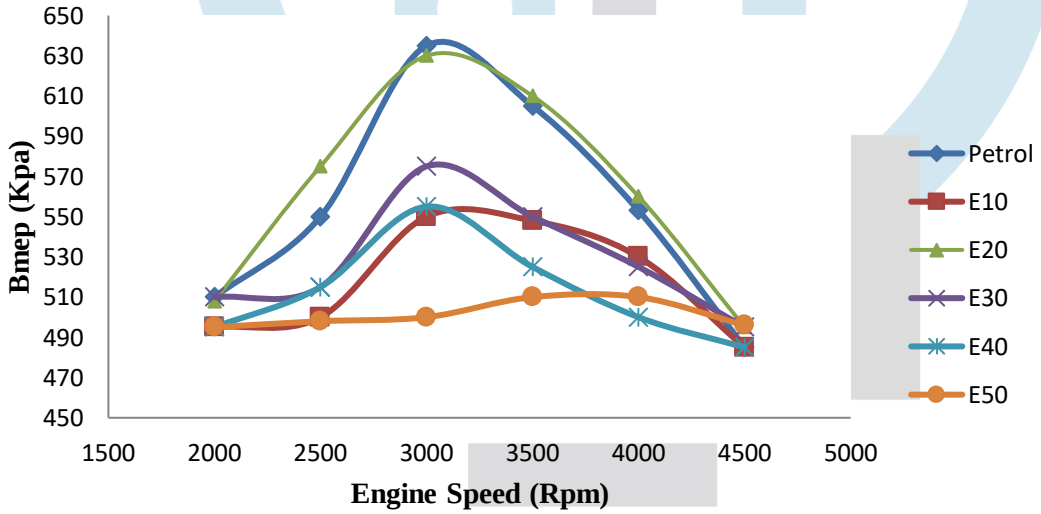

Fig.4.3 Variation of Brake Mean Effective Pressure with Engine Speed for Different Fuels

4.1.4 BRAKE THERMAL EFFICIENCY (%):

Figure 4.4 illustrates how the ethanol-petrol combination affects the test engine's braking thermal efficiency. Up until a maximum value, the brake thermal efficiency progressively improved with an increase in engine speed before declining with further acceleration. The decreased combustion efficiency caused by a shorter period for complete combustion is what causes the fall in brake thermal efficiency at higher engine speeds.

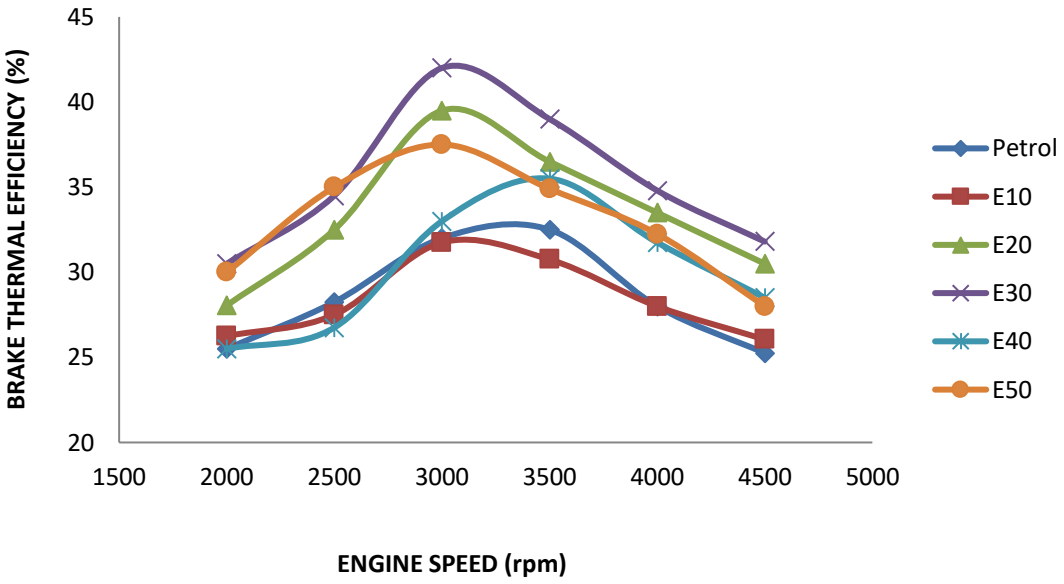

Fig.4.4 Variation of Brake Thermal Efficiency with Engine Speed for Different Fuels

4.1.5 BSFC (kg/kWh):

The BSFC, which depends on the link between volumetric fuel induction, fuel density, and lower heating value, is a ratio between the mass flow of the tested fuel and effective power. The fluctuation of BSFC with relation to engine speed is shown in Fig. 4.5 for all fuel samples. It demonstrates that compared to gasoline, E10, E40, and E50 have higher brake-specific fuel consumption rates whereas E20 and E30 have lower rates. For gasoline, E10, E20, E30, E40, and E50, respectively, the minimum BSFC of 0.248kg/kWh, 0.273kg/kWh, 0.217kg/kWh, 0.228kg/kWh, 0.262kg/kWh, and 0.282kg/kWh was reached.

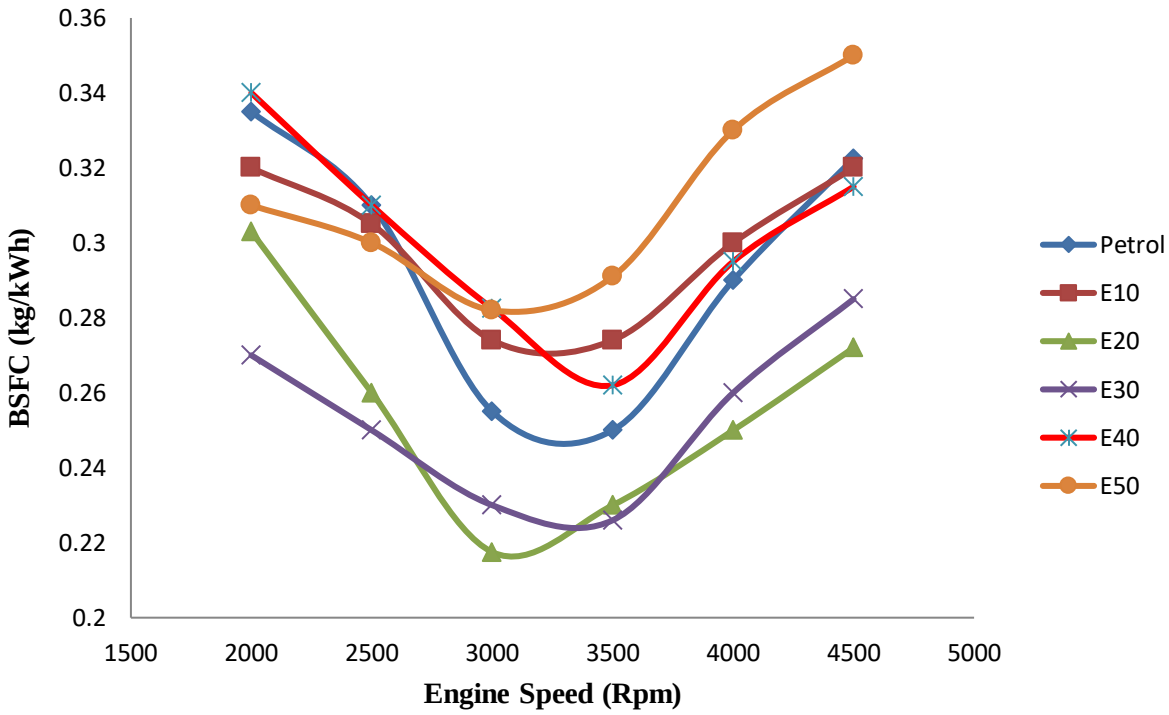

Fig.4.5 Variation of BSFC with Engine Speed for Different Fuels

4.2 EXHAUST EMISSION

Figures 4.6 to 4.9, which represent the influence of blend on CO, CO2, HC, and O2 emissions measured at various engine speeds.

4.2.1 CO (% VOL.):

When there is not enough oxygen for the carbon in the fuel to completely burn into CO2, carbon monoxide is created. This happens when there is a rich air-fuel mixture in the combustion zone. Figure 4.6 illustrates how the ethanol-petrol mixture affects CO emission. It demonstrates that when ethanol level in blends increases, CO emission decreases. This is due to ethanol's increased oxygen content compared to gasoline, which promotes more complete burning. Additionally, it demonstrates how engine speed increases CO emission. Because there isn't enough time for complete combustion at higher engine speeds, there are more CO emissions.

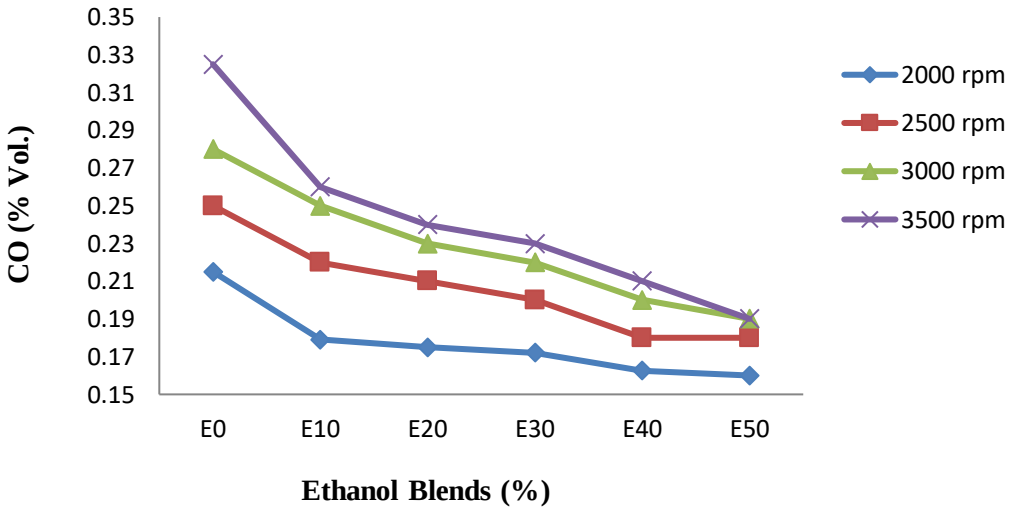

Fig.4.6 Effect of Blends on CO Emission at Different Engine Speed

4.2.2CO_2(% Vol.):

Figure 4.7 depicts the impact of an ethanol-petrol combination on CO2 emissions. As the percentage of ethanol in the blend grows, CO2 emissions rise, and they fall as engine speed rises. When compared to CO concentrations, CO2 concentrations behave differently. This is because the ethanol fuel's high oxygen concentration leads to a better combustion process.

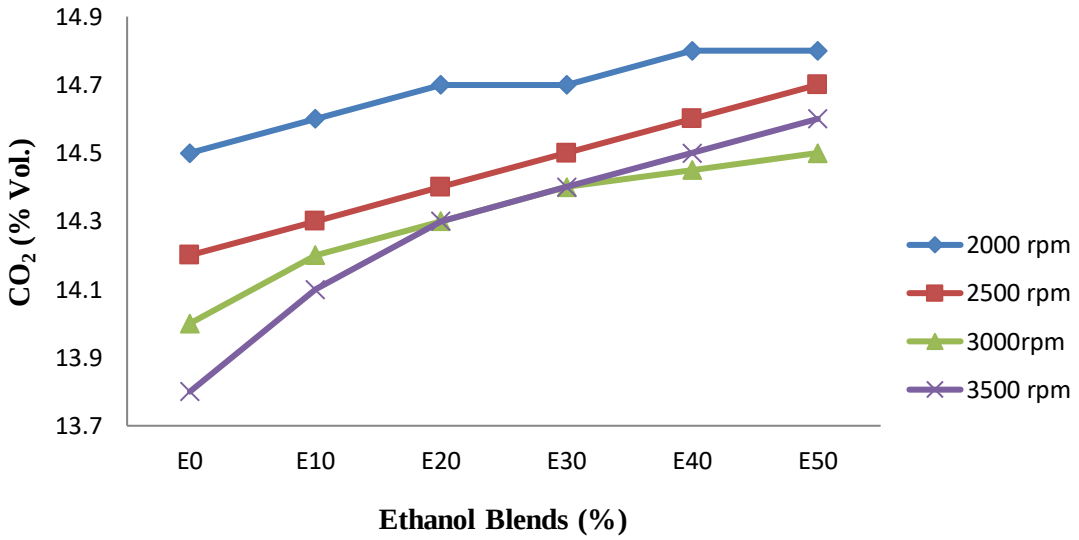

Fig.4.7 Effect of Blends on CO_2 Emission at Different Engine Speed

4.2.3 HC (Ppm):

The impact of changing engine speeds on HC emission while using an ethanol-petrol combination. As the amount of ethanol in the blend rises, it is evident that HCEmissions decrease. This is due to ethanol fuel's increased oxygen concentration, which promotes more complete combustion and lowers HC emission.

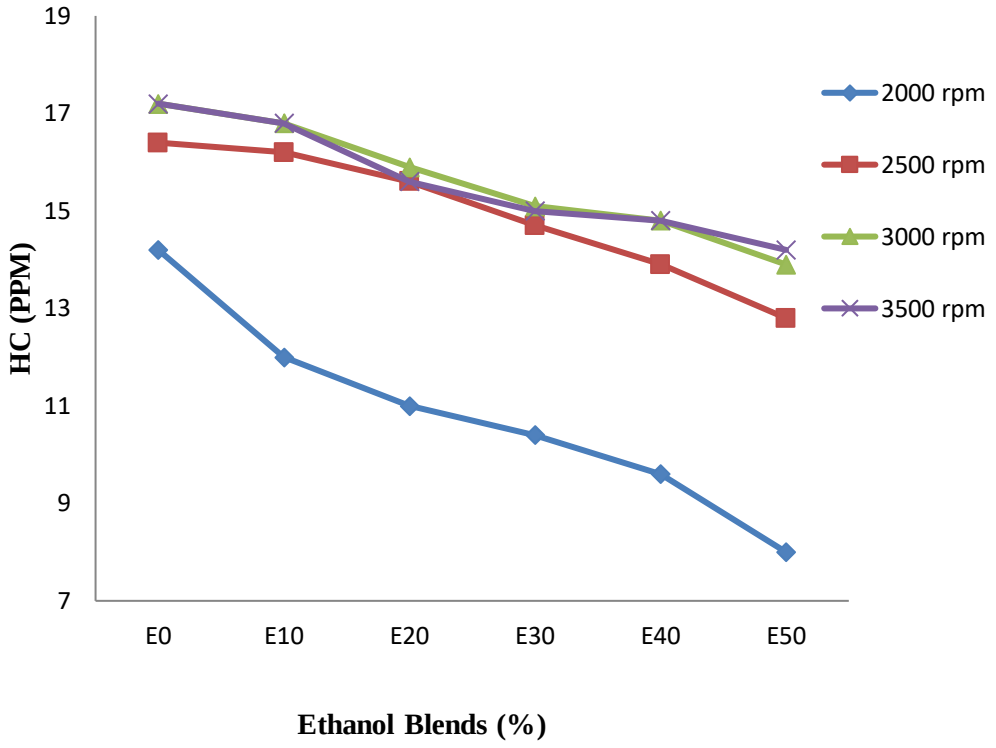

Fig.4.8 Effect of Blends on HC Emission at Different Engine Speed

4.2.4O2(% Vol.):

As seen in Fig.4.9, oxygen emission first reduces as the percentage of ethanol in the mix is increased until it reaches a minimal value, at which point it increases as the percentage of ethanol content is increased even further. Due to ethanol's higher oxygen content than gasoline, oxygen emissions rise at higher ethanol-to-petrol blend ratios.

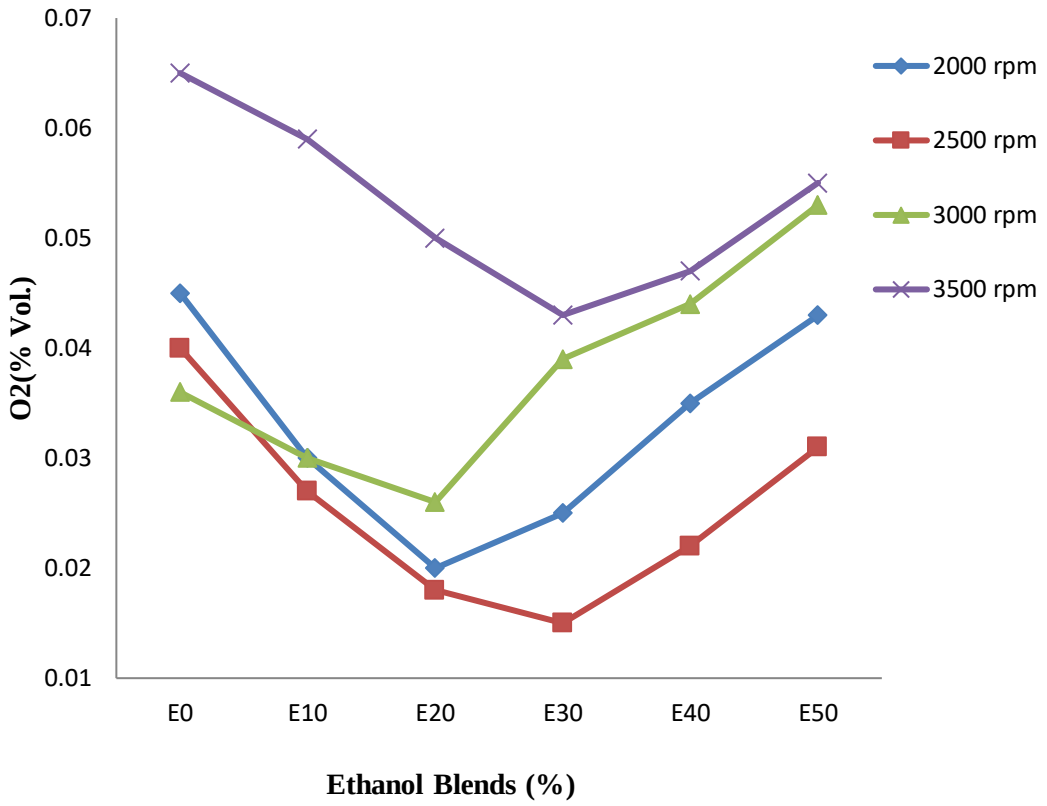

Fig.4.9 Effect of Blends on Excess Oxygen at Different Engine Speed

4.3 COMBUSTION PARAMETERS

4.3.1 Maximum Pressure Developed (Bar):

Figures 4.10 and 4.12, respectively, depict the impact of an ethanol-petrol blend and the impact of engine speed on the maximum pressure created in the cylinder. With engine speed, the maximum pressure created rises steadily. At low engine speeds, it likewise rises with an increase in the percentage ethanol concentration and falls with an increase in the ethanol content at higher engine speeds. There is no discernible difference in the pressure created at 2500 rpm across the various ethanol and gasoline mixtures.

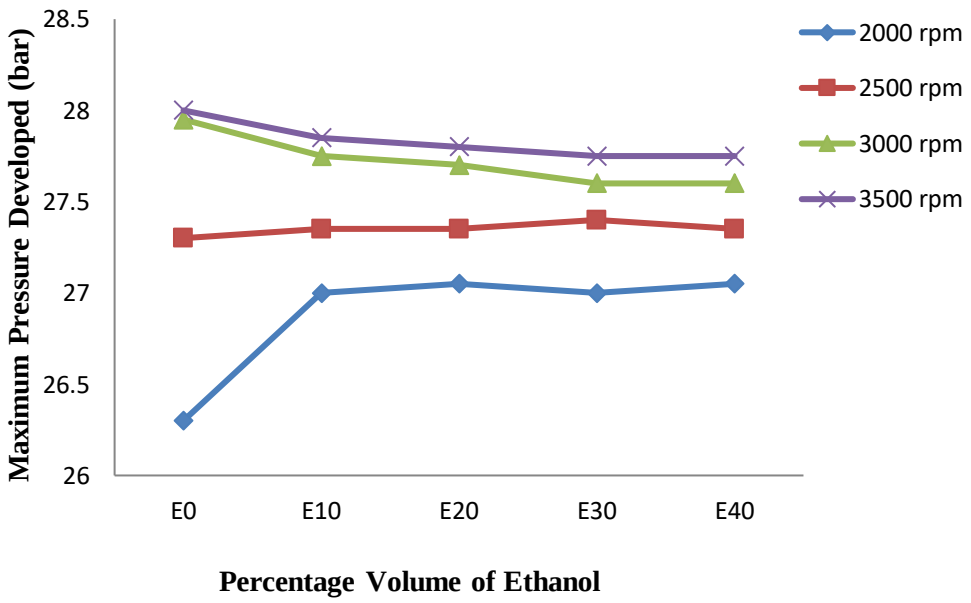

Fig.4.10 Effect of Blend on Maximum Pressure Developed

4.3.2 Maximum Pressure Developed (Bar):

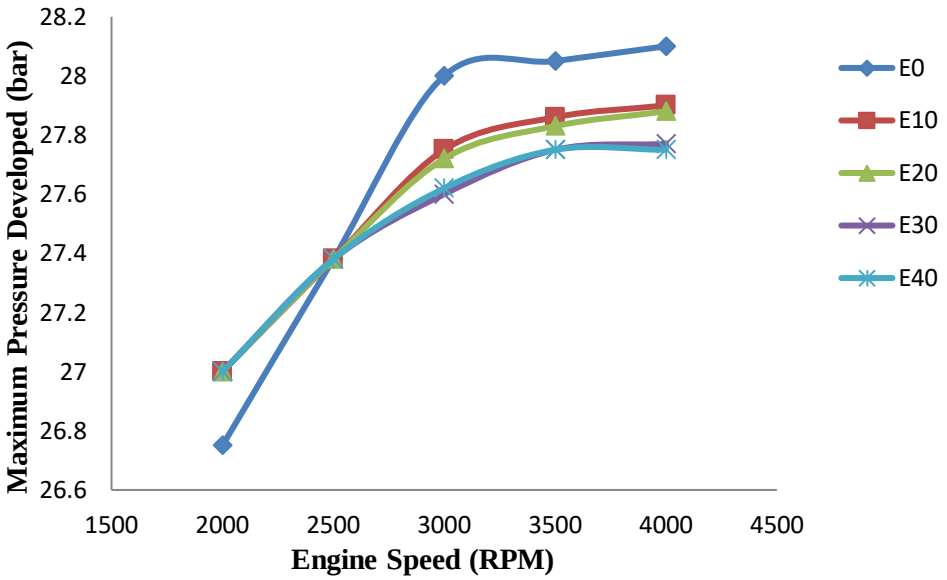

Fig.4.11 Maximum Pressure Developed for Different Fuel

4.3.3 Exhaust Gas Temperature (^{0}C):

The effect of blend on the estimated measured exhaust gas temperature are shown in fig.4.12 .The maximum exhaust gas temperature was found for the petrol.

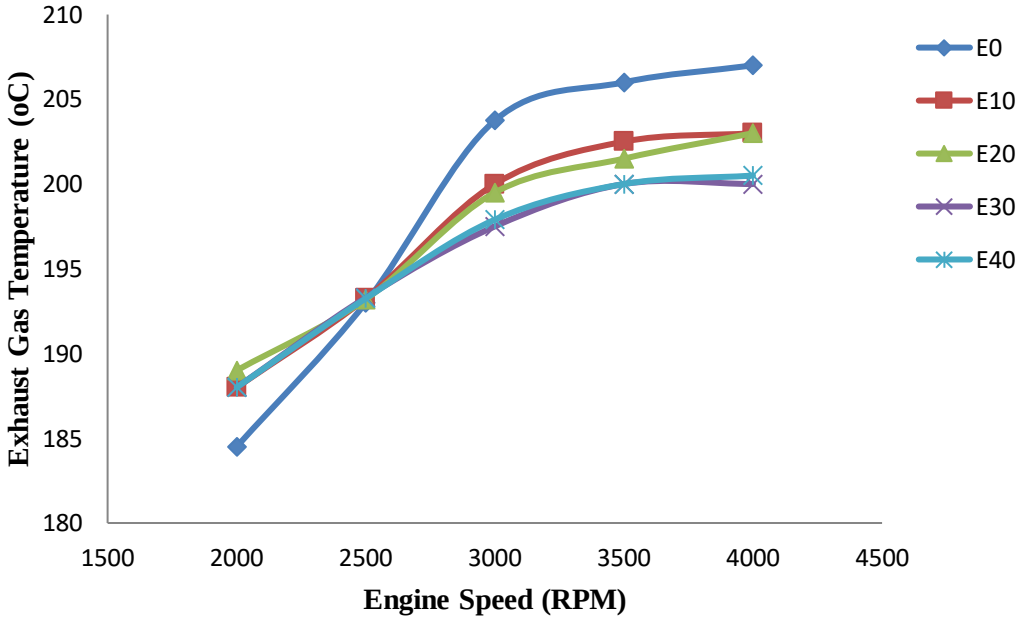

Fig.4.12 Measure Exhaust Gas Temperatures for Different Fuels

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSIONS

The purpose of the current research project is to undertake in-depth analyses of the performance parameters and emission characteristics of single-cylinder, four-stroke gasoline engines employing ethanol-gasoline blends in a variety of volumetric ratios. In order to gather data on the performance parameters and emission characteristics of spark ignition engines for a variety of parameters chosen based on the system's and operating conditions' practical considerations, experiments were conducted. To ascertain the improvement in performance characteristics and decrease in the controlled emissions, results have been contrasted with those of earlier work conducted by other researchers under comparable circumstances. To clearly show the impact of these factors on the improvement of performance metrics and subsequent decrease in the regulated emissions, the data has been displayed as load variation with ethanol-gasoline blends in varied proportions at a constant engine speed. These results make it simple to determine the mix that will give the spark ignition engine the optimum performance and the fewest permitted emissions.

From the research presented here, the following conclusions have been drawn:

- The generated blends' octane number is raised by varying the amount of ethanol added to gasoline. As a result, the compression ratio and power output rise, increasing the mixes' brake thermal efficiency.
- Blends of ethanol and gasoline result in a significant decrease in CO and HC emissions. However, greater ethanol-petrol mixtures result in a noticeable increase in CO2 emissions, indicating more thorough burning.
- The test engine's exhaust emissions are significantly reduced when ethanol is added to gasoline as a fuel additive. Fuel containing ethanol showed improved CO and HC emissions, higher brake thermal efficiency, and higher maximum pressure created at low engine speed.
- The tendency of adding ethanol to gasoline to increase flame speed allows for the ethanol blends' spark timing to be optimised. With a high volume of ethanol in the blend, this will enhance engine performance. Therefore, stronger mixes should be used more frequently to improve the environment; nevertheless, spark timing must be delayed.
- The torque that the engine produces is increased by the addition of ethanol.

Overall, the performance characteristics of ethanol and its blends with gasoline revealed patterns that were comparable to those of gasoline, demonstrating their suitability as alternative fuels for spark ignition engines.

5.2 FUTURE SCOPE

1. In order to employ blends without experiencing any engine running issues, engine adjustments need be made.
2. Blending ethanol with different fuels may produce the best results.
3. SI engines with a single cylinder could likewise be the subject of experiments.
4. To achieve the best results, combine gasoline with some other alcohol derivatives. 5) You can experiment with the ethanol's optimal value to get a better performance analysis.
5. Using gasoline combined with ethanol, experiments can be carried out on CI engines as well to compare their performance to that of SI engines.
6. Additional research on the characteristics of heat transport and combustion behaviour for various fuel blends should be done for other engine types.9)
7. Various Non-regulated emissions can also be analysed in near future.

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INDEX

TABLE 4.1 TORQE

SPEED / BLEND	2000	2500	3000	3500	4000	4500
Petrol	6.7	7.125	8.2	7.75	6.9	6.3
E10	6.45	6.5	7.15	7.1	7.125	6.3
E20	6.6	7.45	8.5	8	7.4	6.45
E30	6.7	6.75	7.5	7.2	6.8	6.45
E40	6.6	6.75	7.5	7.15	6.75	6.4
E60	6.45	6.455	6.5	6.6	6.6	6.45

TABLE 4.2BRAKE POWER (KW)

SPEED / BLEND	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**
Petrol	1.2	1.8	2.2	2.45	2.5	2.45
E10	1.1	1.15	1.8	2.1	2.375	2.4
E20	1.2	1.7	2.15	2.4	2.45	2.5

E30	1	1.4	2	2.2	2.4	2.5
E40	1.1	1.2	1.8	2.05	2.2	2.4
E50	1.1	1.2	1.5	1.75	2	2.2

TABLE 4.3BMEP (Kpa)

SPEED / BLEND	2000	2500	3000	3500	4000	4500
Petrol	510	550	635	605	553	485
E10	495	500	550	548	530	485
E20	508	575	630	610	560	495
E30	510	515	575	550	525	495
E40	495	515	555	525	500	485
E50	495	498	500	510	510	496

TABLE 4.4BRAKE THERMAL EFFICIENCY (%)

SPEED / BLEND	2000	2500	3000	3500	4000	4500
Petrol	25.5	28.25	32	32.5	28	25.25
E10	26.25	27.5	31.75	30.75	28	26.05
E20	28.05	32.5	39.5	36.5	33.5	30.5
E30	30.5	34.5	42	39	34.8	31.8
E40	25.5	26.75	33	35.5	31.75	28.5
E50	30	35	37.5	34.9	32.25	28

TABLE 4.5BSFC (kg/kWh)

SPEED / BLEND	2000	2500	3000	3500	4000	4500
Petrol	0.335	0.31	0.255	0.25	0.29	0.3225
E10	0.32	0.305	0.274	0.274	0.3	0.32
E20	0.303	0.26	0.2175	0.23	0.25	0.272
E30	0.27	0.25	0.23	0.226	0.26	0.285
E40	0.34	0.31	0.2825	0.262	0.295	0.315
E50	0.31	0.3	0.282	0.291	0.33	0.35

TABLE 4.6 CO (% Vol.)

BLEND / SPEED	E0	E10	E20	E30	E40	E50
2000 rpm	0.215	0.179	0.175	0.172	0.1625	0.16
2500 rpm	0.25	0.22	0.21	0.2	0.18	0.18
3000 rpm	0.28	0.25	0.23	0.22	0.2	0.19
3500 rpm	0.325	0.26	0.24	0.23	0.21	0.19

TABLE 4...7CO2(% Vol.)

BLEND / SPEED	E0	E10	E20	E30	E40	E50
2000 rpm	14.5	14.6	14.7	14.7	14.8	14.8
2500 rpm	14.2	14.3	14.4	14.5	14.6	14.7
3000rpm	14	14.2	14.3	14.4	14.45	14.5
3500 rpm	13.8	14.1	14.3	14.4	14.5	14.6

TABLE 4.8 HC (PPM)

BLEND / SPEED	E0	E10	E20	E30	E40	E50
2000 rpm	14.2	12	11	10.4	9.6	8
2500 rpm	16.4	16.2	15.6	14.7	13.9	12.8
3000 rpm	17.2	16.8	15.9	15.1	14.8	13.9
3500 rpm	17.2	16.8	15.6	15	14.8	14.2

TABLE 4.9 O2(% Vol.)

BLEND / SPEED	E0	E10	E20	E30	E40	E50
2000 rpm	0.045	0.03	0.02	0.025	0.035	0.043
2500 rpm	0.04	0.027	0.018	0.015	0.022	0.031
3000 rpm	0.036	0.03	0.026	0.039	0.044	0.053
3500 rpm	0.065	0.059	0.05	0.043	0.047	0.055

TABLE 4.10 MAXIMUM PRESSURE DEVELOPED (Bar)

Blend / speed	E0	E10	E20	E30	E40
2000 rpm	26.3	27	27.05	27	27.05
2500 rpm	27.3	27.35	27.35	27.4	27.35
3000 rpm	27.95	27.75	27.7	27.6	27.6
3500 rpm	28	27.85	27.8	27.75	27.75

TABLE 1.11 MAXIMUM PRESSURE DEVELOPED (Bar)

SPEED(rpm) / BLEND	2000	2500	3000	3500	4000
E0	26.75	27.38	28	28.05	28.1
E10	27	27.38	27.75	27.86	27.9
E20	27	27.38	27.72	27.83	27.88
E30	27	27.38	27.6	27.75	27.77
E40	27	27.38	27.62	27.75	27.75

TABLE 4.12 EXHAUST GAS TEMPERATURE (^{o}C)

SPEED(rpm) / blend	2000	2500	3000	3500	4000
E0	184.5	193	203.75	206	207
E10	188	193.25	200	202.5	203
E20	189	193.2	199.5	201.5	203
E30	188	193.3	197.5	200	200
E40	188	193.25	197.9	200	200.5