Comparative Analysis of Combustion and Emission of Ethanol and Gasoline on SI Engine

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Abstract – The automobile plays an important role in the transportation system. With an increase in population and living standard, the transport vehicles as well as car population is increasing day by day and this leads to increase in pollution. Petroleum-based fossil fuels are the dominant energy source for transportation. Recently, ethanol is being increasingly used as a fuel additive and is emerging as an alternative to carbon-neutral transportation. This thesis reviews the serviceability of ethanol as a clean, cheap and renewable substitute fuel for spark ignition engines and discusses the comparative chemical and physical properties of ethanol and gasoline fuels. The differences in the properties of ethanol and gasoline fuels are sufficient to create a significant change during the combustion phase of engine operation and affect the performance of spark-ignition engines. Furthermore, the effects of ethanol, and its blends with gasoline fuel, engine performance parameters and emission characteristics have been highlighted.

Indexed Terms- combustion, emission, ethanol, gasoline, SI engine.

I. INTRODUCTION

With the rapid development of the global economy, the consumption of crude oil products is currently increasing rapidly. The problems resulting from the prominent use of fossil fuels such as global warming, depletion of fossil fuel resources and environmental deterioration have become serious challenges threatening the continuous development and sustainable progress of human society. Therefore, research activities have been focused to find out the viable alternative fuels for meeting sustainable energy demand with minimum environmental impact. The promising substitutes for petroleum fuels include bio-fuels, mainly biodiesel and ethanol.

Ethanol is a renewable energy source and it can be produced from many bio-sources such as sugarcane, grain, maize and beet roots. Ethanol, like most short-chain alcohols which is flammable, volatile and colorless liquid. In general, ethanol burns cleaner than petroleum fuel. Ethanol can reduce greenhouse gas emissions, as the plants used for ethanol production absorb carbon dioxide. By the start of the 21st century, large scale commercial use of ethanol as a fuel had started. The burning of fossil fuels produces around 21.3 billion tons of carbon dioxide per year, but it is estimated that natural processes can only absorb about half of that amount, and there is a net increase of 10.65 billion tons of atmospheric carbon dioxide per year. A global movement towards the generation of renewable energy is therefore under way to help reduce global greenhouse gas emissions.

II. REVIEW OF ETHANOL

Ethanol is also called alcohol, ethyl alcohol and drinking alcohol. It is a simple alcohol with the chemical formula C2H6O and is often abbreviated as EtOH [4]. Where in the early 1990s, Brazil is the leading user of using ethanol in spark ignition engine due in part to its role as the globe's leading producer of ethanol. Gasoline sold in Brazil contains at least 25% anhydrous ethanol. Hydrous ethanol (about 95% ethanol and 5% water) can be used as fuel in more than 90% of new gasoline fueled cars sold in the country. The United States and many other countries primarily use E10 (10% ethanol, known as gasohol) and E85 (85% ethanol) ethanol/gasoline mixtures. Ethanol has been used as rocket fuel and is currently in lightweight rocket-powered racing aircraft [4].

A. Properties of ethanol and gasoline

The properties of ethanol are described in Table 2.1.

Table 1. Ethanol Properties

Chemical Formula	C_2H_5OH
Density at 15°C	0.789 kg/L
Boiling Point at 1 bar	78°C
Melting Point	-114.5°C
Molecular Weight	46.07
Stoichiometric Air-fuel Ratio	8.94
Lower Heating Value	26.8 MJ/kg
Higher Heating Value	29.7 MJ/kg
Research Octane Number	111

The properties of gasoline are mentioned in Table 2.2.

Table 2. Gasoline Properties

Chemical Formula	C_8H_{18}
Density at 15°C	0.77 kg/L
Boiling Point at 1 bar	30 ~ 225°C
Melting Point	-57.1 ~ -56.6°C
Molecular Weight	114
Stoichiometric Air-fuel Ratio	14.7
Lower Heating Value	44.5 MJ/kg
Higher Heating Value	46.4 MJ/kg
Research Octane Number	90-98

B. Importance of ethanol

The use of ethanol as fuel has the potential of reducing greenhouse gas emissions by 40-45% compared to gasoline because the plants used for its production absorb carbon dioxide during the growth process. In recent times, ethanol has been commonly used as a fuel additive or an alternative fuel in spark ignition engines and compression ignition (diesel) engines. The use of ethanol in spark ignition engines becomes attractive due to the fact that it burns cleanly and relatively has high octane number. Currently, there are three ways of using ethanol fuel in spark ignition engines: the use of pure ethanol, ethanol-gasoline blends and the use of gasoline-ethanol dual-fuel port injection systems [3].

C. Ethanol and its blends

There are two important mixture combinations. They are E85 (flex fuel) and E10 (gasohol). The number after the 'E' indicates the percentage of ethanol by volume. E10, a fuel mixture of 10% anhydrous ethanol and 90% gasoline can be used in the internal combustion engines of most modern automobiles and light-duty vehicles without need for any modification on the engine or fuel system. These blends are rated as being 2 to 3 octane numbers higher than regular gasoline [2]. E10 reduces the use of gasoline with no modification needed to the automobile engine.

E85, a mixture of 85% ethanol and 15% gasoline, is generally the highest ethanol fuel mixture found in the United States and several European countries. This mixture has an octane rating of 94-97, which is significantly lower than pure ethanol but still higher than normal gasoline [2]. This mixture eliminates some of the pure alcohol e.g. cold starting, tank flammability, etc. [1].

D. Combustion reaction of the ethanol

Combustion of ethanol is a simple process. Ethanol and oxygen combine in a chemical reaction with the help of a little bit of energy. The reaction results in a significant release of energy in the form of heat and light, as well as the formation of carbon dioxide and water. The chemical reaction of combustion of ethanol is as below:

$$C_2H_6O+O_2 \rightarrow 2CO_2+3H_2O+\text{heat energy}$$

III. EXPERIMENTAL SETUP AND MEASUREMENT PARAMETERS

Engine performance is an indication of the degree of success of the engine performs its assigned task. The performance of an engine is evaluated on the basis of the following:

1. Specific Fuel Consumption
2. Brake Mean Effective Pressure
3. Specific Power Output
4. Specific Weight
5. Exhaust Smoke and Other Emissions

For the evaluation of an engine performance, few more parameters are chosen and the effect of various operating conditions, design concepts and modifications on these parameters are studied [8]. The basic performance parameters are the following:

1. Power and Mechanical Efficiency
2. Mean Effective Pressure and Torque
3. Specific Output
4. Volumetric Efficiency
5. Fuel-air Ratio
6. Specific Fuel Consumption
7. Thermal Efficiency and Heat Balance
8. Exhaust Smoke and Other Emissions
9. Specific Weight

The main purpose of running an engine is to obtain mechanical power. Power is defined as the rate of doing work and is equal to the product of force and linear velocity or the product of torque and angular velocity. Therefore, the measurement of power involves the measurement of force or torque as well as speed [8]. The force or torque is measured with the help of a dynamometer and the speed by a tachometer.

The power developed by an engine and measured at the output shaft is called brake power (bp) and is given by,

$$bp = \frac{2\pi NT}{60}$$

where, T = torque (N-m)
N = rotation speed in revolutions per minute (rpm)

A. Engine Performance Test

After checking the necessary conditions, the engine switch is turned on. The engine starting handle is pulled out and the engine would start to run. As soon as the engine is running, time is measured using the stopwatch and engine speed is collected by digital tachometer. Then, the exhaust gas emission sensor is placed in the exhaust manifold to know the contaminants and volumes of exhaust gases. The amount of exhaust gas emissions is collected with exhaust gas analyzer and the engine is stopped. Then the data are collected at different engine speeds.As seen in the Figure 4.3, digital tachometer is used in measuring engine speed and engine speed is displayed in revolutions per minute. Engine speed can be measured by placing tachometer in front of the engine rotating shaft.

Figure 1. Digital Tachometer

The length and diameter of tube are measured to calculate the volume of fuel flow meter tube. Time is collected using the stopwatch when the engine is running. Then, the volume is calculated. The engine speed is measured by digital tachometer by placing the infrared sensor in the center of the engine shaft when the engine is running. The exhaust gas emission sensor is placed in the exhaust manifold to know the exhaust contaminants and amounts of exhaust gases by volume. The results are displayed in the exhaust gas analyzer.

B. Measuring Data

The measuring data such as fuel consumption; speed are showing with the tables.

Table 3. Measured Data of Engine Performance Test by Using Ethanol Fuel

Engine Speed (rpm)	Fuel Volume (mL)	Fuel Consumption Time for Ethanol (sec)	Fuel Consumption Time for Gasoline (sec)
1450	0.02	10.13	13.4
1550	0.02	9.54	15.27
1650	0.02	8.96	16.15
1750	0.02	8.12	17.93

In Table 3, the measured data of engine performance tested with ethanol and gasoline are described.

IV. COMPARISON OF ENGINE PERFORMANCE

In this section, comparison of fuel consumption, air-fuel ratio and brake specific fuel consumption are described.

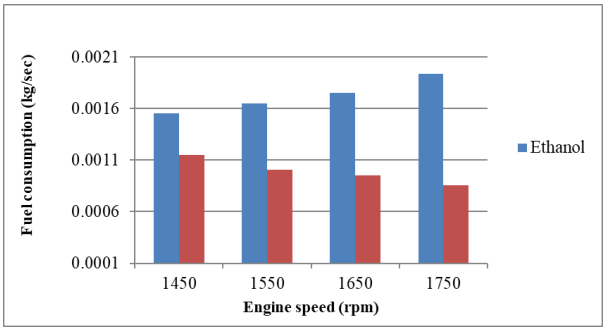

Figure 2. Comparison of Mass of Fuel Consumption

In the Figure 2, the comparison mass of fuel consumption is described. Fuel consumption of ethanol is higher than gasoline because ethanol consumed much fuel as the engine speed increases. Fuel consumption of gasoline decreases as the engine speed increases while fuel consumption of ethanol increases as the speed increases.

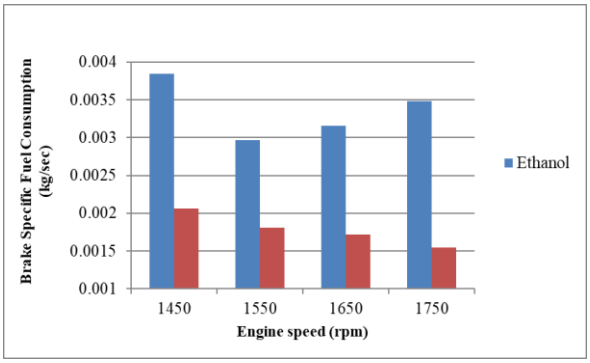

Figure3. Comparison of Brake Specific Fuel Consumption varied with speed

The Figure 3 represents a comparison of brake specific fuel consumption for ethanol and gasoline. As seen in Figure 3, brake specific fuel consumption of ethanol is higher than gasoline because ethanol has lower heating value and higher fuel consumption, ethanol has higher brake specific fuel consumption. It is tested under no-load condition and calculated with engine rated output of 2 kW. So the results may have some uncertainties.

V. COMPARISON OF EXHAUST GAS EMISSION

In Figure 4, the comparison of carbon dioxide emission of ethanol and gasoline is mentioned. The emission of carbon dioxide is maximum at the speed of 1480 rpm for ethanol. For gasoline, the result of carbon dioxide emission is maximum at the speed of 1580 rpm.

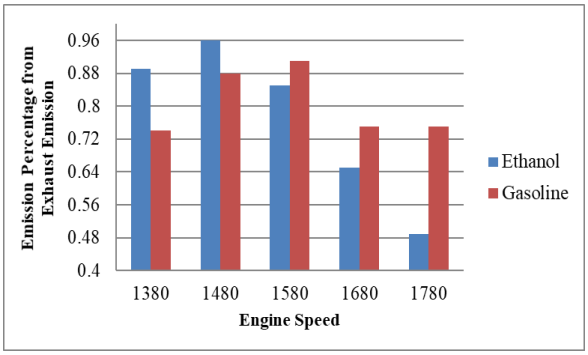

Figure 4. Comparison of Carbon Dioxide Emission

In the Figure 5, comparison of carbon monoxide emission is described. The emission of carbon monoxide is maximum at the speed of 1380 rpm. For gasoline, the result of carbon monoxide emission is

maximum at the speed of 1380 rpm. Carbon monoxide emission of ethanol gradually decreases as the engine speed increases while carbon monoxide emission of gasoline increases while the speed increases.

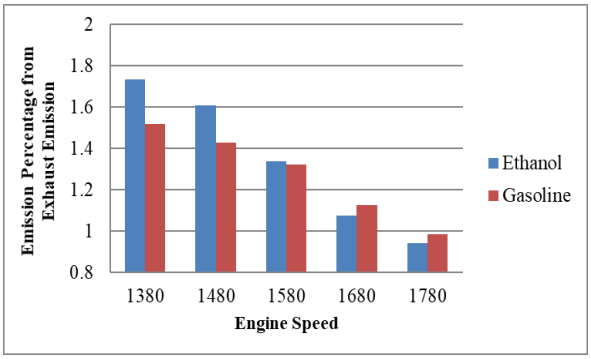

Figure 5. Comparison of Carbon Monoxide Emission

A comparison of hydrocarbon emissions is mentioned in Figure 6. The results of hydrocarbon emission from ethanol are maximum at the speed of 1380 rpm but decreases when the engine speed increases. The results of hydrocarbon emission of gasoline are maximum at the speed of 1380 rpm. The reason is that residual gas emission is not sufficient the oxygen content in inlet manifold.

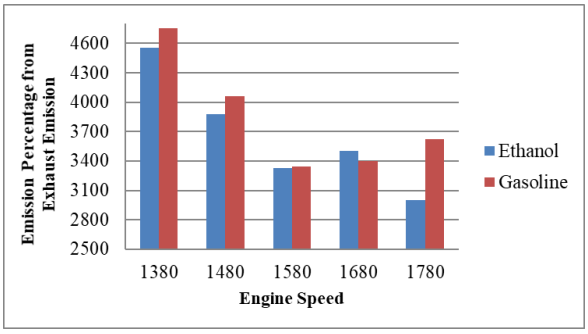

Figure 6. Comparison of Hydrocarbon Emission

VI. CONCLUSION

Alternative fuels are becoming more relevant for vehicles because of the depletion of fossil fuel reserves and environmental concerns. Ethanol is considered as a green and clean renewable alternative fuel for spark-ignition engines. As ethanol is a renewable energy source and can be produced from natural resources, the emissions from automobiles which use ethanol fuel can affect less pollution to the environment than gasoline.

This thesis examined ethanol and gasoline with specific focus on the following issues: (1) Properties of ethanol fuel, (2) Combustion and performance of ethanol fuel in SI engines and (3) Emissions from ethanol fuel in spark ignition engines. Comparative study of combustion and emission by using ethanol and gasoline in SI engine has been investigated.

To meet the objectives of study, spark ignition engine is tested at various engine speeds such as 1380, 1480, 1580, 1680 and 1780 rpm are tested. For combustion characteristics, in terms of fuel consumption, engine running with ethanol consumed much fuel when compared to gasoline running. Brake specific fuel consumption of ethanol is higher than gasoline since ethanol has lower heating value and higher fuel consumption.

For emission characteristics, from the standpoint of air-fuel ratio, ethanol produces higher value than gasoline. However, equivalence ratio of ethanol is less than that of gasoline.

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REFERENCES

[1] Pulkrabek Willard W., 1997. “Engineering Fundamentals of the Internal Combustion Engine”.

[2] “Common Ethanol Fuel Mixtures”,https://en.wikipedia.org/wiki/comm om_thanol_fuel_mixtures

[3] Musaab Faroung, Fuwu Yan, Majo Luo and Richard Fiifi Trukson, “Spark Ignition Engine combustion, Performance and Emission Products from Hydrous Ethanol and Its Blends with Gasoline”.

[4] “Ethanol”, https://en.wikipedia.org/wiki/Ethnol

[5] “The major differences between ethanol and gasoline”,https://www.bellperformance.com/bl

og/the-major-differences-between-ethanol-and-gasoline.
[6] "Advantages and Disadvantages of Bioehtanol", bioethanol-np.blogspot.com
[7] V Ganesan, Dept of Mechanical Engineering IIT Madras, Chennai, 2007, "Internal Combustion Engines".
[8] Colin R. Ferguson and Allan T. Kirkpatrick, 2016, "Internal Combustion Engines", 3rd Edition.
[9] "Air-Fuel Ratio", https://en.wikipedia.org/wifi/Air_fuel_ratio
[10] TBMC-AGE "Exhaust Gas Analyzer", www.edibon.com