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Simulation Study on Single Cylinder Spark Ignition Engine with Varying Ethanol Gasoline Blends

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ABSTRACT

This study investigates the effect of a mixture of ethanol and gasoline in a four-cylinder cycle spark ignition OHV engine in a cylinder fitted with a generator. The simulation is performed in professional engine simulation software from AVL Austria designated as BOOST. AVL BOOST is used as a computational thermodynamic simulation tool to analyze performance and emission characteristics for individual mixtures of ethanol and gasoline (0%, 10%, and 30% of ethanol by volume). . Studies are performed for 40%, 50%, 60%, 70%, 80%, 90%, 100% load conditions for constant engine speed. The results were compared to pure gasoline. This showed that as ethanol content increases, power and torque decrease. Fuel consumption increases with an increase in ethanol percentage. CO emissions decrease with an increase in ethanol percentage while HC emissions decrease at higher percentage loads. NOX emissions increase with increase in ethanol percentage.

KEYWORDS: *Engine, Simulation, Alternative fuel, Performance, Gasoline, Emission*

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1. INRODUCTION

The automotive sector is the largest sector in the world that uses various fuels as well as automobiles which are easy and reliable sources for transportation and power generation. The power developed by an automobile basically depends on the fuel used for combustion. Gasoline and diesel are basic fuels in liquid form that have been used extensively in the world since the last century. These fuels are derived from crude oil, which is available in limited quantities in the world. The demand for fossil fuels is increasing rapidly due to the increase in automobile vehicles, due to which the resources of crude oil are rapidly decreasing. This situation will create a problem for future energy crisis. In fact, with the worldwide increasing number of automobiles and the growing demand for emerging economics, demand will probably increase even more. Transport fuel demand is generally satisfied with fossil fuel demand. However, the resources of these fuels are depleting, fossil fuel prices are expected to increase and fossil fuel combustion has an adverse effect on climate [1].

Alternative fuel spark ignition shows great compatibility and reliability with gasoline for engines. This helps to improve performance as well as reduce air pollution from the exhaust pipe of the spark ignition engine. This section reviews the contributions made by researchers in the field of alternative fuels for spark ignition engines. Mourad and Mahmood [2] focus on the incorporation of various additives in gasoline to reduce pollutant emissions and increase fuel economy. Gasoline was mixed with ethanol and butanol in various proportions to examine their effect on engine performance under different operating conditions. The mixed ratios of gasoline and ethanol were 2, 5, 10, 15 and 20%. Engine fuel consumption and pollutant emissions were measured for all mixtures at different engine speeds under reduced loading. The experimental results showed a clear reduction in the emissions of pollutants emitted by engines 13.7% for carbon monoxide and 25.2% for hydrocarbons, as well as fuel consumption by 8.22%. However, engine power was negatively affected and could reach 11.1% for fuel blends. Zhu et al., [3] have conducted experimental studies on the water rates of fire of pools containing ethanol-gasoline mixtures under low ambient pressure. In this study, the burning rates of blending fuel in a full-scale cargo compartment with ambient pressures of 40kPa, 61kPa, 80kPa, 101kPa were mainly investigated. A 20 cm round pool filled with fuel was employed at 0%, 10%, 20%, 50%, 80% and 100% by volume. The mass burn rate, flame temperature, fuel temperature as well as flame images were measured and analyzed. The results indicate that as the ambient pressure is low, the burning rate decreases, and the flame height increases significantly, but only the temperature in the flame base region is clearly affected. With the increase in ethanol ratio, the burning rate shows a non-monotonic variation that has a peak value, and the maximum value varies with pressure at a fixed ethanol ratio; But the maximum value of flame height and flame temperature is about 20% in ethanol ratio and ambient pressure of 40kPa, and shows a monotonic decrease in relative large pressure. A simple empirical correlation to the burn rate data is developed based on the ratio of ambient pressure, stoichiometric ratio and combustion to heat of evaporation, indicating a good agreement with 15% deviation. Martha N. Palabourn [4] has found that the use of ethanol-gasoline mixtures increases the emission of formaldehyde, acetaldehyde and acetone by 5 to 14 times by comparison. Even though a mixture of ethanol increases the production of aldehyde, it has less harmful effects than petrol. Shifter et al. [5] introduced combustion and emission behavior for ethanol gasoline blends in single cylinder engines. In this work, various performance and exhaust emissions were analyzed on a single cylinder SI engine at 2000 rpm. The tested fuel range varies from E0 to E20. The result suggests that E10 has a slight effect in combustion rate compared to pure gasoline but E20 slows down the combustion process and increases cyclic dispersion. Fang et al. [6] mentioned that when methanol burns in an engine, it produces toxic gas formaldehyde, whereas ethanol requires more land and water resources to produce but butanol is the next generation biofuel supplements Or may substitute gasoline. Butanol can also be produced from renewable sources and used as an industrial solvent. Since butanol is less corrosive, due to which it can adapt to the fuel. Due to its physical and chemical properties, butanol can be transported easily through pipeline lines.

2. PRESENT WORK
In the present investigation AVL BOOST has been used to analyze the effect of blending ethanol with gasoline in various concentrations. A mixture of ethanol for gasoline varying from 0% to 30% was used in simulations for varying load conditions. The engine specifications are given in Table 1. The weight percentages of ethanol and gasoline in the ethanol – gasoline mixture are given in Table 2.

Table1: Engine specification

S. No.	Type	
1	Bore (mm)	65.09
2	Stroke (mm)	61.91
3	Connecting rod length (mm)	123.82
4	Compression ratio	9
5	Maximum power (Kw)	4.8 (at 3600 rpm)
6	Maximum torque (N-m)	4.71 (at 3600 rpm)
7	Engine displacement volume (cm^3)	206
Source: Whispower AG 2500E		

Table2: Weight percentage of ethanol and gasoline in ethanol-gasoline blend

Sample Designation	Ethanol (Weight%)	Gasoline (Weight%)
E0	-	100
E10	10	90
E30	30	70

3. SIMULATION MODELLING
The BOOST program package consists of an interactive pre-processor that assists with the preparation of input data for the main computation program. Results analysis is supported by an interactive post-processor. Calibration of the gasoline engine must be done first. On the basis, a simulation model has been established for using ethanol fuel engines. The model can be designed by first placing elements in the work area and attaching them to the pipe. Alternatively elements can be placed in the required order (AVL List GmbH, AVL Boost - User Guide, 2009). Figure 1 shows the model built: The model consists of the following elements: 1 cylinder (C), 1 air cleaner (CL), 1 injector (I), 2 system limits (SB), 3 plenums (PL), 3 restrictions. (R), 7 measuring points and 11 pipes (number).

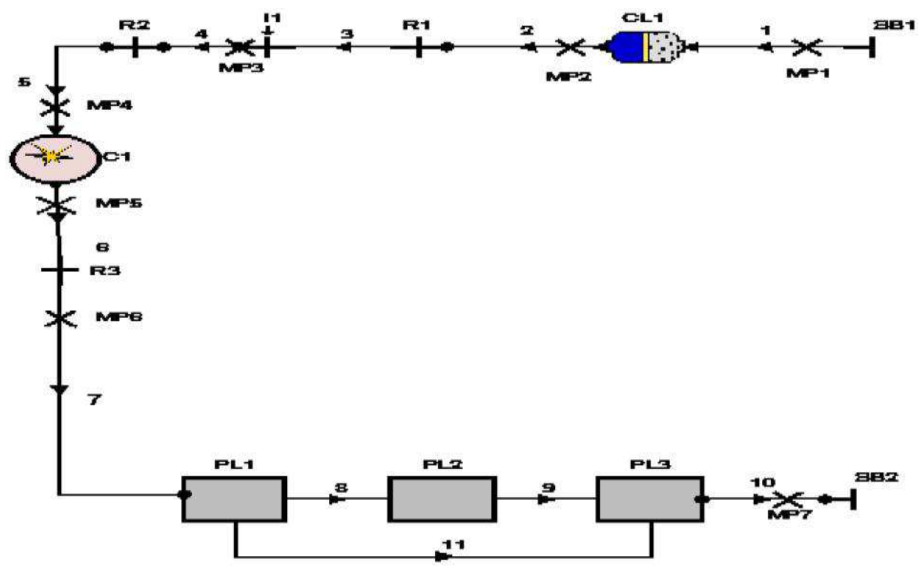

Figure 1: Model of the Engine

4. RESULTS AND DISCUSSION

The present study focuses on the emission and performance characteristics of ethanol – gasoline mixtures. Different concentrations of mixtures (E10 to E30 by volume) were analyzed using AVL BOOST for 40% to 100% load conditions under constant engine speed. The results are divided into different subsections based on the parameters analyzed.

4.1. Effect of Load on Power and Torque

Figures 2 and 3 illustrate the effect of load on torque and power, respectively. The increase in torque and power along with the increase in percentage load is due to the presence of more oxygen resulting in complete combustion and increased power. In addition, it has been observed that pure gasoline shows higher power and torque than ethanol – gasoline mixtures due to the high calorific value of pure gasoline.

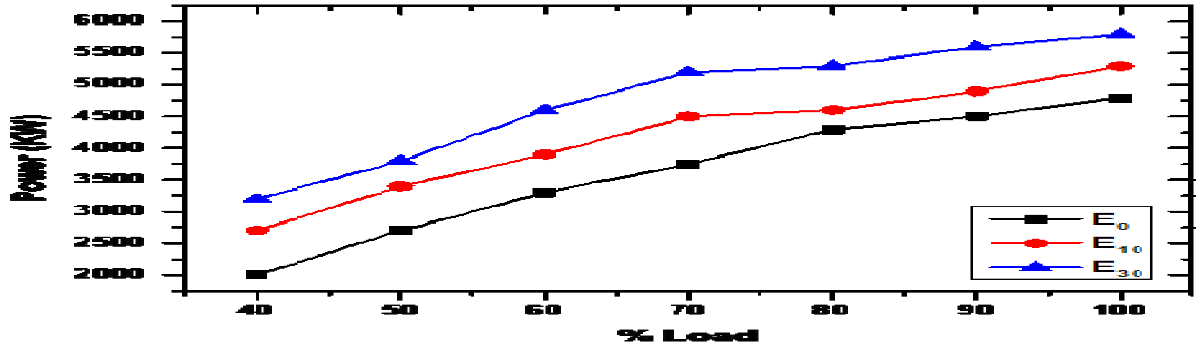

Figure2: Load Vs Power for single cylinder engine

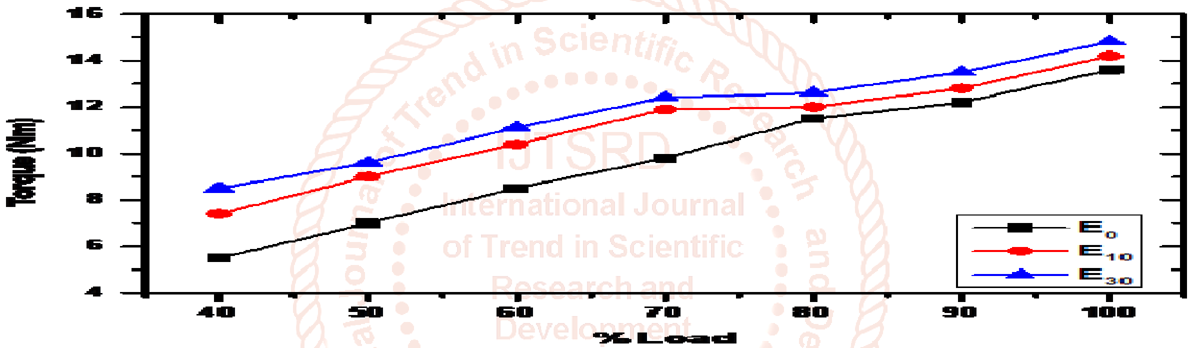

Figure3. Load Vs Torque for single cylinder engine

4.2. Effect of Load on Brake Specific Fuel Consumption (BSFC)

The effect of using ethanol – gasoline blends on brake specific fuel consumption (BSFC) is shown in Figure 4. It is clear from Fig. 4 that the BSFC increases due to the low heat content per unit mass of ethanol. Fuel compared to pure gasoline. Thus, a greater amount of fuel is introduced into the engine for the desired fuel energy input, thus BSFC increases with an increase in ethanol content which is why E30 shows higher BSFC. Petrol is thus more economical than ethanol – gasoline blends.

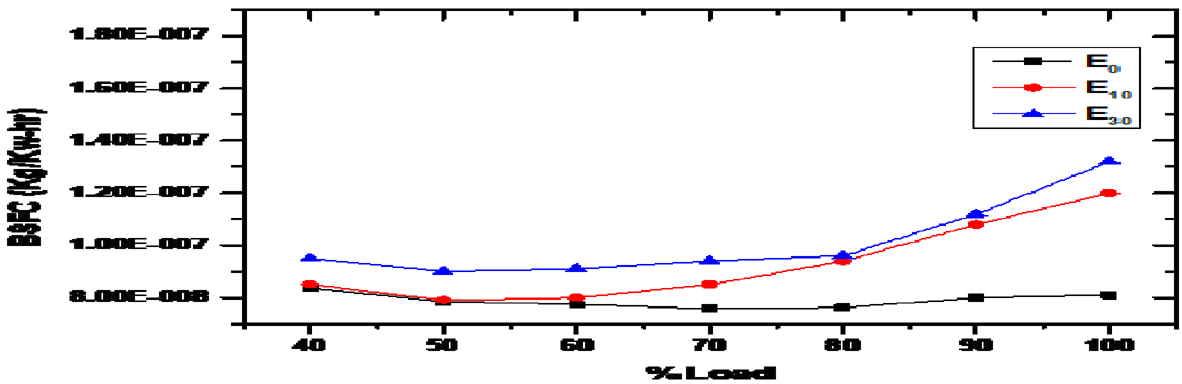

Figure 4 Load Vs BSFC for single cylinder engine

4.3. Effect of Load on Exhaust Gas Temperature

Figure 5 presents the effect of ethanol – gasoline blends on exhaust gas temperature. It is clear from Fig. 5 that increasing the amount of ethanol in the mixture at different engine loads reduces the temperature because ethanol is an oxygen-rich fuel resulting in complete combustion and thus lowering the temperature. The latent heat of ethanol evaporation is 2.64 times higher than gasoline. Ethanol absorbs more heat from the cylinder during evaporation. So the temperature of ethanol's adiabatic flame is lower than gasoline. Thus the E30 reflects a lower exhaust gas temperature because it absorbs more heat during evaporation.

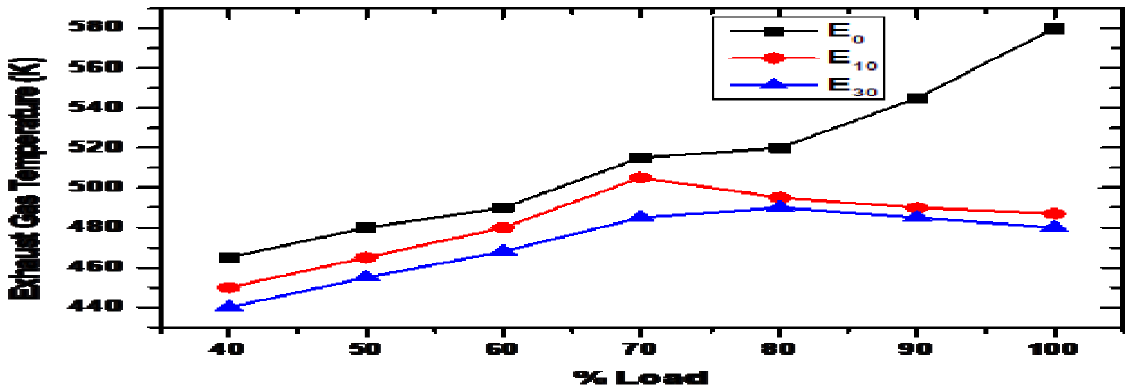

Figure 5 Load Vs exhaust gas temperature for single cylinder engine

4.4. Effect of Load on Carbon Monoxide (CO) Emissions

Figure 6 shows the effect of different fuels on CO emissions at different loads. CO is formed due to incomplete combustion. With the increase of ethanol content, CO decreases because ethanol is an oxygen-rich fuel resulting in better combustion. Thus E30 shows lower CO emissions than gasoline.

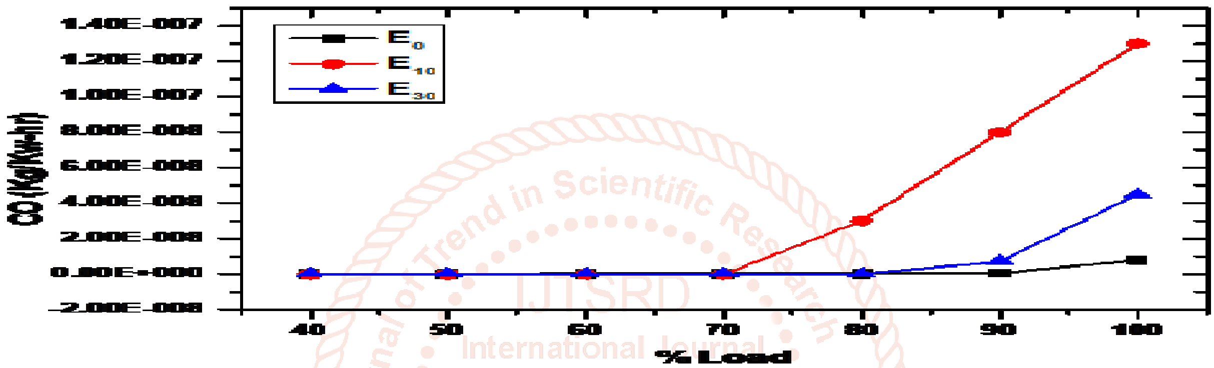

Figure6: Load Vs CO for single cylinder engine

4.5. Effect of Load on Hydrocarbon (HC) Emissions

Figure 7 shows the effect of load on HC emissions. It is clear from Figure 7 that HC emission percentage decreases with an increase in load because the fuel-rich mixture contains enough oxygen to react with all the carbon, thus exhaust products have higher HC emissions. Thus, as the percentage load increases, the fuel is bent and HC emission decreases. Furthermore, more preliminarily ethanol – gasoline blends reflect higher HC emissions than gasoline due to the enriched mixture but HC emissions at full percent load are higher in pure gasoline than ethanol – gasoline blends. The decrease in HC emissions at full load compared to gasoline is due to the greater oxygen content as well as ethanol being an oxygen-rich fuel that reacts with all carbon and hydrogen.

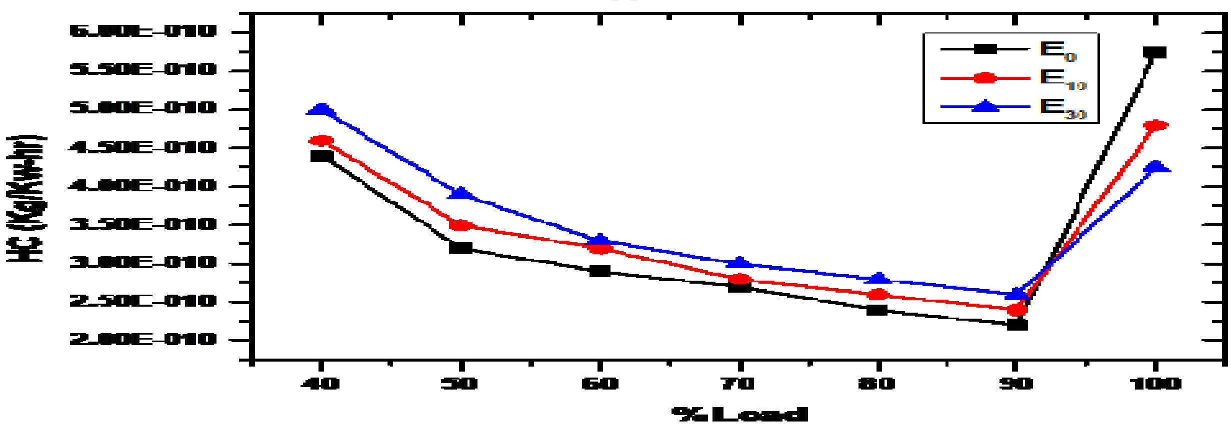

Figure7 Load Vs HC for single cylinder engine

4.6. Effect of load on NOX Emissions

Figure 8 below shows the effect of load on NOx emissions. NOx emissions increase with increasing load for all percentages of ethanol as greater amounts of air will enter the engine with an increase in percentage load resulting in an increase in NOx emissions. With the increase of ethanol content in gasoline, NOx emission increases due to the oxygen content of ethanol, as ethanol supplies oxygen for NOx formation. In addition, the latent heat of vaporization is higher for ethanol resulting in higher pressures and temperatures than pure gasoline. High pressure and temperature inside the cylinder may be another reason that explains the increase in NOx formation.

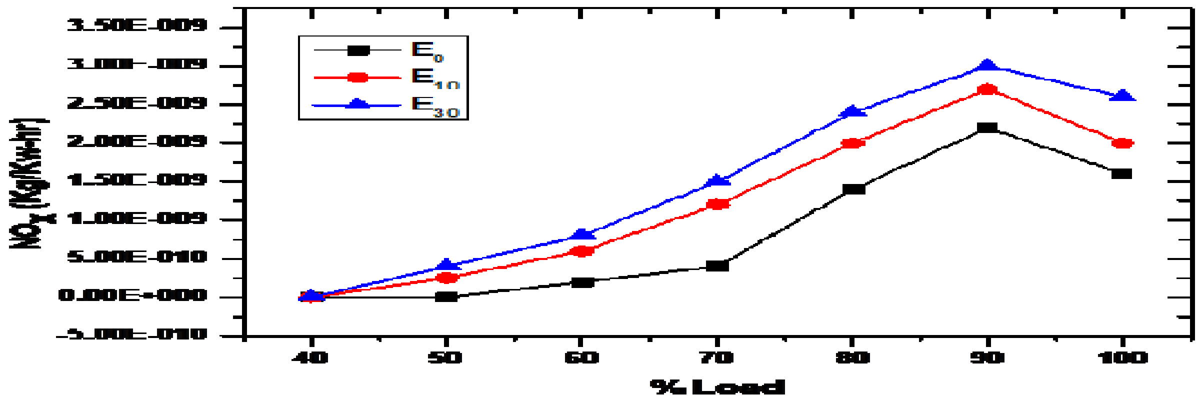

Figure8 Load Vs NO_X for single cylinder engine

5. CONCLUSION

1. Ethanol can be used as an alternative fuel in petrol engines.
2. There was a decrease in torque and power with increasing ethanol percentage.
3. The increase in CO emission decreases with ethanol percentage while HC emission decreases at higher emission loads.
4. NOx emissions for ethanol – gasoline blends are higher than gasoline.

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