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Performance Analysis of SI Engine using Blend of Butanol and Ethanol with Gasoline

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ABSTRACT: In this report, performance analysis of multi cylinder spark ignition engine has been evaluated on ethanol gasoline blend with or without butanol addition. Ethanol was added with gasoline in three different volumetric ratio as 10,20 and 30 percent. Butanol was added in the volumetric ratios of 2.5, 5, 7.5 and 10 percent with ethanol gasoline and gasoline. Various performance parameters of the engine such as bsfc, BTE, BSEC and EGT have been observed. Exhaust emission such as carbon monoxide, hydrocarbon and oxides of nitrogen has also been observed. The results show that addition of butanol in ethanol gasoline blends had positive effect on the engine performance. Emissions of CO and HC found to be lower compared to ethanol gasoline blends and gasoline. While NOX emission was on higher side. Overall, additive blends have been performed well and found suitable without any hardware modification of the engine.

KEYWORDS: SI Engine, Butanol, Ethanol, Biofuel, Brake Horsepower, Gasoline, Brake, Thermal Efficiency

I. INTRODUCTION

The Automobile industry is the largest sector in the world which uses various fuels and is reliable source for transportation and power generation. The power developed by an automobile basically depends upon the fuel used for the combustion. Petrol and Diesel are the basic fuels in liquid form which are extensively used in the world from the last century. These fossil fuels are derived from crude oil, available in limited quantity in the world. The demand of fossil fuel is rising rapidly because of increase in vehicles due to which the resource of crude oil is depleting rapidly. The present situation will create a problem for energy crises in the future. In fact, with a worldwide increase in the number of automobiles and a rising demand of emerging economics demand will probably rise even harder. Transport fuel demand is generally satisfied by the fossil fuel demand. However, resources of these fuels are decreasing, prices of fossil are expected to rise and the combustion of fossil fuels has adverse effects on environment.

The reliance on fossil fuel is increasing day by day but the combustion of these fuels and also affecting the climate of the earth. The greenhouse gasses are increasing due to increase in number of vehicles. Many efforts are made by numerous countries to fix the value of exhaust emissions coming out from the automobiles. Still there is a lot of work to do for accomplishing of the hydrocarbon fuels with same alternative fuels like alcohols, ethers etc. due to their compatible properties with hydrocarbons. About 75 percent of the total crude oil of India is met through imports. Total import of crude oil by India was about 189.238 MMT which cost about Rs. 8,64, 875 Crore during 2013-14. The total production of crude oil was 37,778 MMT in 2013-14. In recent years, the consumption of crude oil in India has been increasing at an annual rate of 5- 6%. (MoPNG,2014). If the use of alcohol as engine fuel is encouraged in India, then apart from saving foreign exchange, the farmers would be motive to cultivate the crops like potato, sugarcane etc. this will increase the production of alcohol through which the air quality increase.

In terms of exhaust emission, both type of alcohols helps in the reduction of CO and UHC emission.

Bio-fuels: Bio fuels are gaseous or liquid fuels produced from biomass resources and used in place of, or in addition to, diesel, petrol or other fossil fuel for transport, stationary portable and other applications. Example of biofuels is alcohols (ethanol, menthanol, butanol etc.) biodiesel (liquid oils and animal fat). Green diesel (derived from algae or other plant source) and biogas (methane derived from animal manure and other digested organic matter).

Types of Bio-fuels: Bio-fuels are the important source of clean energy generation but still a lot of research work to be required for the easy and cheap availability of bio fuels. Based on the energy generation for different types of system, bio fuel can be divided into following type.

- First generation bio fuel
- Second generation bio fuel
- Third generation bio fuel

First Generation Bio-fuels: These are the bio-fuels which derived from sources like starch, vegetable oil, sugar and animal fats etc. First generation bio-fuels also known as conventional bio-fuels. These types of bio-fuel are directly related to the biomasses which are edible. Examples of first generation bio-fuels are alcohols, bio-diesel, bio-ether, bio-gas etc.

Second Generation Bio-fuel: Second generation bio fuels are those bio-fuels which can be manufactured from various types of biomass. Second generation bio fuel are made from wood crops, agriculture residues or waste and municipal solid waste. Second generation bio fuels are also known as advanced bio-fuel because they required some technique for fuel extraction and are non-edible. Example of second generation bio-fuels are biohydrogen, bi methanl, wood diesel, mixed alcohols, syn gas etc.

Third Generation Bio-fuel: The Third Generation bio-fuels which are derived from algal biomass. Third generation bio-fuels are new in this stream. From this kind of biofuel different type of fuel can be made. They improve certain properties of the fuel when blended with gasoline in certain amount. Examples are bio-diesel, bio-ethanol, hydrogen from microalgae etc. Bio-fuels like alcohols have some advantages over gasoline which make them substitute or partial replacement of gasoline in spark ignition engine. The fuel property restricts in blending with gasoline. Up to 20 percent volume of ethanol can be easily blended with gasoline without engine modifications. Butanol can be blended with gasoline at any concentrations. The other fuel property is oxygenates. Since gasoline contain almost zero oxygen which leads to improve combustion inside the cylinder as well as the emission of the harmful gasses from the exhaust of the engine. While ethanol consists 35 percent oxygen and butanol contains 21 percent oxygen which yields in the reduction of harmful gasses from the exhaust of the engine. Another important property is octane rating. Octane rating is a measure of the amount of pressure and temperature is required to ignite the fuel – air mixture. High octane fuels reduce knocking inside the internal combustion engine which leads to reduce premature combustion inside the cylinder, Butanol –gasoline blends don't separate in the presence of water while ethanolgasoline blend do. Butanol can be transported through pipeline while ethanol can't because it could be contaminated with water.

II. TESTING PROCEDURE

The tests were carried in S.I. ENGINE LABORATORY OF THE DEPARTMENT OF MECHANICAL ENGINEERING. ALL SAINTS' COLLEGE OF TECHNOLOGY, BHOPAL (M.P). In this chapter, experimental details, various parameters studied and methodology used in the analysis are described in detail. This paper deals with the brief description of experimental set-up, test engine, fuel measurement, exhaust gas analyzer and details about the instruments used. It also described the methodology used for the measurement of various parameters and their analyses.

Test Engine: A Hindustan Motor make four stroke, four cylinder MPFI gasoline run engine having 8.5:1 compression ratio selected for the study. The engine is commonly used in Ambassador cars for transportation. The specifications of the selected engine are shown in Table 1.

Table 1: Specification of Engine

Make	Hindustan Motor
Model	Ambassador
Number of Cylinder	4
Bore (mm)	84
Stroke (mm)	82
Displacement Volume (cc)	1817
Cooling System	Water Cooled

Fuels and Their properties: The experiments were carried out using butanol, ethanol with gasoline as engine fuel. The volume percentage of butanol was carried from 2.5-10 percent and used as an additive. The volume percentage of ethanol was kept from 10-30 percent. The gasoline volume percentage was adjusted per the volume required. Total sixteen blends were prepared for the study.

Gasoline; Gasoline is a hydrocarbon fuel which contains carbon molecular in number varying from 4 to 12. Gasoline is also known as petrol or motor spirit and produced by distillation of crude oil. Gasoline is not miscible with water and its relative density varying from 0.72-0.78. Gasoline octane rating is varying from 84 to 95. It also having negligible amount of oxygen molecule. On burning, gasoline produced black smoke which is highly toxic for human being. For this study, IOCI marked gasoline was obtained from the University's filling station.

Ethanol: Ethanol ($\text{CH}_3\text{CH}_2\text{OH}$), an oxygenated organic carbon compound, is also known as Ethyl alcohol. It is a small chain high octane alcohol with molecular weight as 46 and containing 35 percent oxygen. Ethanol has high octane quality for spark ignition applications. The concentration of Ethanol is expressed as degree proof which represents twice the concentration of Ethanol. A 200° proof Ethanol, anhydrous or absolute Ethanol, has 100 percent concentration of Ethanol. Ethanol, on burning does not produce a single trace of black smoke and having a tag of clean burning fuel. Ethanol can be obtained from molasses by fermenting the carbohydrates. During the fermentation, the carbon dioxide is removed after forty hours and a fully fermented material is formed called mash. By distillation, the ethanol vapours are produced from the mash. Alcohol can also be obtained from potatoes. Alcohols are also obtained from fermentation of the vegetable waste material, such as tropical grass, straw etc.



Figure 1: Engine Setup



Figure 2: Fuel Consumption unit

III. RESULTS AND DISCUSSION

The graphs shown are for relative density. Gross heat of combustion, flash and fire point, brake specific fuel consumption, brake thermal efficiency, brake specific energy consumption, exhaust gas temperature and engine exhaust emission with respect to engine speed.

Stability of blends at room temperature

The stability and homogeneity was checked at room temperature which varied from 28°C to 34°C, lasting from more than 30 days of their preparation. 20 ml samples of different combination of additive/gasoline and ethanol/additive/gasoline were prepared. A total Sixteen were prepared of the tested with butanol as an additive. All tested blends were kept at room temperature for thirty days and then kept in refrigerator for next thirty days at a temperature of 4°C. It was days observed that all the tested fuel blends were stable and there was no phase separation shown by the tested fuels.

Fuel Properties

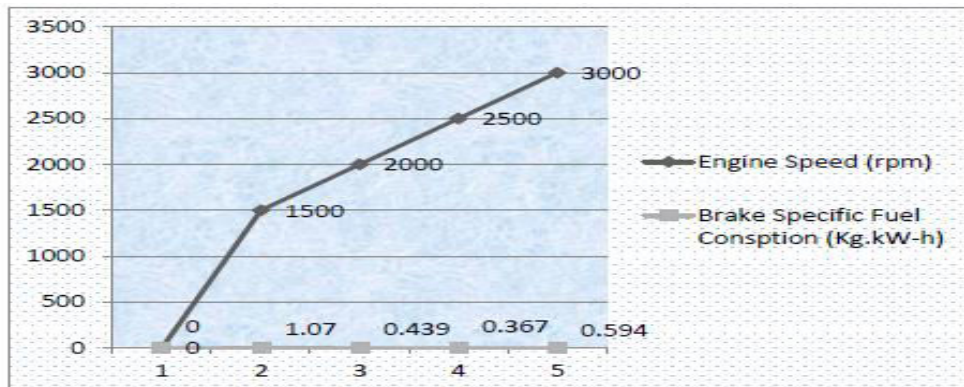
The values of fuel properties such as relative density, gross heat of combustion flash and fire point of the selected fuel types were determined.

Relative density

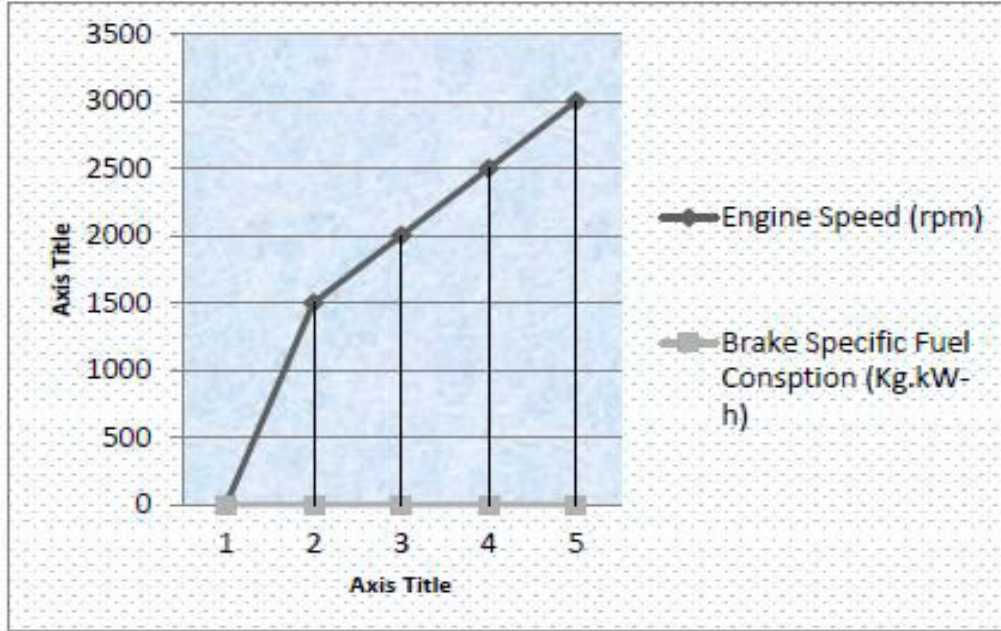
The graphs showed that the relative density of gasoline was observed 0.730. The relative density of gasoline was observed by Koc et al. (2009) is in the range of 0.0690-0.790 and that by Zhang et al.(2015) as 0.730. The relative density of butanol was observed as 0.810 which is similar as reported by Zhang et al. (2015). The relative density of butanol was also mentioned by Elfasakhany (2016) as 0.810. The relative density of all fuel type were observed to be 0.736, 0.738, 0.740, 0.741 for E10 blends, 0.743, 0.744, 0.746, 0.747 for E20 blends and 0.748, 0.749, 0.751, 0.753 for E30 blends with 2.5, 5, 7.5 and 10 percent additive respectively. It is observed that API gravity is closer to gasoline for all tested fuel type. API gravity of butanol is 30.7 percent lower than gasoline.

Table-2: Engine Performance Test Results of Hindustan Motor Make Ambassador Engine on Gasoline Fuel Ambient Temperature: 24 °C

Engine Speed (rpm)	Brake Specific Fuel Consumption (Kg.kW-h)	Brake Thermal Efficiency (%)	Brake Specification Consumption (MJ/kW-h)	Exhaust Gas Temperature (K)	Carbon Monoxide (%)	Hydrocarbon (ppm)	Oxides of Nitrogen (PPm)
1500	1.07	8.85	45.9	556	0.677	145	275
2000	0.439	16.80	18.9	615	0.587	94	316
2500	0.367	19.10	15.76	654	0.620	84	675
3000	0.594	14.10	25.51	704	0.591	68	1290



(a)



(b)

Figure 3: Brake Specific Fuel Consumption

Gross heat of combustion

The gross heat of combustion for gasoline and different blends of ethanol with and without butanol additive are shown in the fig. 4.2 (a) to (d). The graphs indication that the gross heat of combustion of gasoline was bserveed 42.95 Mj.kg. Canakei et al. (2013) reported the gross heat of combustion of gasoline as 42.60 MJ/kg. The gross heat of combustion of gasoline was reported by Costagliolaet al.(2013) as 42.7 MJ/kg and that by Zhang et. al (2015) was 43.4 Mj.kg. The gross heat of combustion for butanol was found 32.71 MJ/kg/ Varol et al. (2014) reported the gross heat of combustion for butanol as 33 MJ/kg. Zhang et al/ (2015) also reported the gross heat of combustion for butanol was 33.1 Mj/kg.

Table-3 Engine Performance Test Results of Hindustan Motor Make Ambassador Engine on 2.5% Butanol Additive – Gaoline Blended Fuel

Engine Speed (rpm)	Brake Specific Fuel Consption (Kg.kW-h)	Brake Thermal Efficiency (%)	Brake Specification Consumption (MJ/kW-h)	Exhaust Gas Temperature (K)	Carbon Monoxide (%)
1500	0.844	10	36	527	0.590
2000	0.530	15.9	22.63	597	0.537
2500	0.432	19.5	18.44	645	0.587
3000	0.618	13.5	26.38	602	0.541

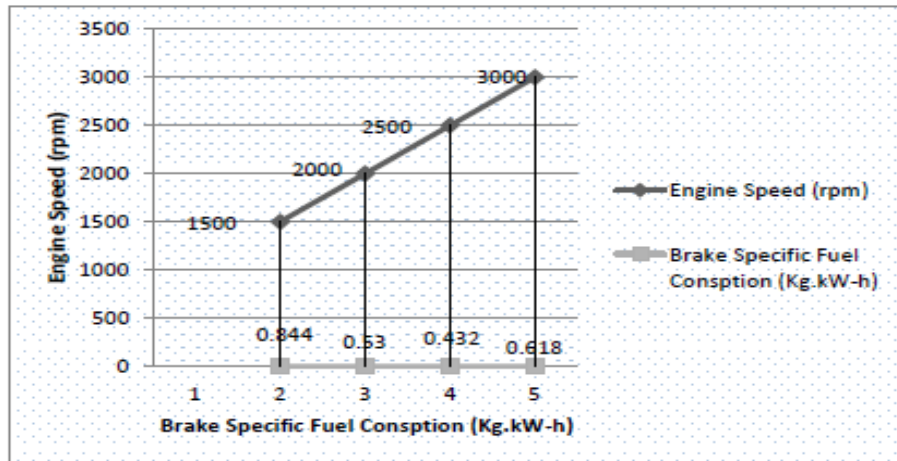


Figure 4: Engine Speed

IV. CONCLUSION

The properties of the tested fuels were evaluated. Performance and emission evaluation of the engine on tested fuels was conducted. On the basis of the result obtained the following conclusions were drawn.

(I) The blends were prepared on the volume basis. The butanol-gasoline blends were prepared by adding 2.5, 5, 7.5 and 10 percent butanol to gasoline. The ethanol-gasoline blends were prepared by adding 10, 20 and 30 percent of ethanol (200° proof) to gasoline and butanol was used as an additive in the blends. The butanol was added in varying value of 2.5, 5, 7.5 and 10 percent by volume in E10, E20 and E30 blends. All the blends were found stable and there was no phase separation in the temperature range of -4 °C and 28 °C to 34°C even after 30 days of blends formation.

(II) The relative density of ethanol-gasoline blends increase with increase in butanol addition.

(a) The relative density at 15°C of gasoline was found to be 0.730 and for E10 blends with butanol additive was found 0.736, 0.738, 0.740, and 0.741 for 2.5, 5, 7.5 and 10 percent respectively.

(b) The relative density at 15°C of E20 blends with butanol additive was found 0.743, 0.744, 0.746, and 0.747 for 2.5, 5, 7.5 and 10 percent respectively.

(c) The relative density at 15°C of E30 blends with butanol additive was found 0.748, 0.749, 0.752, and 0.753 for 2.5, 5, 7.5 and 10 percent respectively.

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