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Effects of Ethanol-Gasoline Blends on Engine Performance and Exhaust Emissions in a Spark Ignition

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ABSTRACT: In the 21st century fossil fuel crises are arising day to day due to drastic consumption and fossil fuel prices are also increasing. On the other side the exhaust emission affected our greenhouse gases and rising global warming. Ethanol is found to be an alternative fuel and additive. It is renewable, bio-based and eco-friendly fuel for spark-ignition (SI) engines. The most attractive properties of ethanol are that it can be produced from renewable energy sources such as sugarcane, cassava, many types of waste biomass materials, corn and cellulosic materials. Further, Ethanol can be used as an additive for reducing exhaust emissions like carbon dioxide. Ethanol has higher evaporation heat, octane number and flammability temperature which can improve engine performance and reduces exhaust emissions. In this study, the effects of gasoline and gasoline–ethanol blends (E5, E10 and E15 and E20) on engine performance and pollutant emissions were investigated experimentally in a spark-ignition engine. The experimental results show that E5 and E10 were found to be the best blend out of all blends which improved performance and reduced emission like CO, HC, CO_2 and NO_X level.

Keywords: Ethanol, properties of blends, performance, emissions.

I. INTRODUCTION

Increasing global concern due to air pollution has generated much interest in the environmental friendly alternative fuels. Alternative fuels for internal combustion engines are also becoming important because of diminishing petroleum reserves and increasing air pollution [1-3]. Methanol and ethanol are good candidates as alternative fuels since they are liquids and have several physical and chemical properties similar to those of gasoline and diesel fuels [4-7]. However, in the past, ethanol was not given expectancy due to its insufficient production and high price India, the world's biggest sugar consumer and a major importer in recent years, produces about 1.5 billion liters of ethanol, although only around a quarter of that is suitable for use as fuel [8,9]. The rest is used for beverages or export. The Indian sugar industry emphasized that producing fuel ethanol would absorb the sugar cane surplus and help the country's distillery sector, which is presently burdened with huge overcapacity, and also allow value adding to byproducts, particularly molasses [10,11]. India's Minister for Petroleum and Natural Gas gave his approval in December 2001 to a proposal to launch pilot projects to test the feasibility of blending ethanol with gasoline. Mid-March 2002 the government decided to allow the sale of E-5 (5% ethanol mix with petrol) across the country. On 13 September, 2002, India's government mandated that nine states and four federally ruled areas will have to sell E-5 by law from 1 January 2003 [12]. Oil companies had needed 363 million liters of ethanol in the 2003/04 year to satisfy the requirement of the 5% mandate, but only 196 million liters had been available due to declining sugarcane output with drought. The second phase, to be initiated before year-end 2004, will spread the programme nationally [13,14]. Alcohol, such as methanol (CH_3OH) or ethanol (C_2H_5OH), is a pure substance. However, gasoline is composed of C_4–C_{12} hydrocarbons, and has wider transitional properties.

Alcohol is one of the fuel additive (Methanol, Ethanol) has some advantage over gasoline such as better antiknock characteristics and the reduction of CO and HC emissions [15,16]. Among alternative fuels, ethanol is one of the fuels employed most widely. Some of its reasons are introduced in the following. First, it can be produced from "cellulosic biomass", such as trees and grasses and is called bio-ethanol. Secondly, ethanol (CH_3CH_2OH) is made up of a group of chemical compounds whose molecules contain a hydroxyl group, OH, bonded to a carbon atom. So, the oxygen content of this fuel favors the further combustion of gasoline [17,18]. In addition, ethanol is commonly used to increase gasoline's octane number. It can be concluded that using ethanol–gasoline blended fuels can ease off the air pollution and the depletion of petroleum fuels simultaneously. Further, it was investigated by various researchers that ethanol-gasoline improved performance and reduced emission in SI engine [19, 20].

The objective of this research was to determine the effect of ethanol blending on the performance and emissions of internal combustion engines that are calibrated to run on 100% gasoline. Experimental tests were performed on an engine using pure gasoline, 5%, 10%, 15% and 20% ethanol blends. The results of the study show that 10% ethanol blends can be used in internal combustion engines without any negative drawbacks.

II. EXPERIMENTAL

Gasoline was blended with ethanol and methanol to prepare four different blends on a volume basis. These are E5 (5% ethanol + 95% unleaded gasoline), E10 (10% ethanol + 90% unleaded gasoline), E15 (15% ethanol + 85% unleaded gasoline), and E20 (20% ethanol + 80% unleaded gasoline). Fuel specifications of the gasoline and ethanol/methanol–gasoline blends were determined as per ASTM and BIS standards. The fuel properties of pure alcohols were obtained from the manufacture companies and the various blends properties has been measured as per ASTM standards. Some properties of the test fuels are shown in Table 1.

Table 1: Physical and chemical properties of gasoline and ethanol, ethanol-gasoline blend.

S. No.	Fuel Properties	Gasoline	Ethanol	E5	E10	E15	E20
1.	Density kg/m^3	758	790	761	765	768	772
2.	Freezing point, ˚C	- 40	- 114	-43	-48	-52	-57
3.	Specific heat, kJ/kg K	2	2.4	2.02	2.04	2.05	2.07
4.	Viscosity, mPa s at 20 ˚C	0.37-.44	1.19	0.41	.45	.49	.53
5.	Lower heating value, 1000 kJ/L	30-33	21.1	32	31.5	31	30.5
6..	Flash point, ˚C	-65	13	-50	-40	-30	-20
7.	Auto-ignition temperature, ˚C	257	380	263	270	275	282
8.	RON	88-100	109	92	92.8	93.5	94.4
9.	MON	83	90	83	83	82.8	81.9

The tests were conducted on a vehicle, which has a three-cylinder, four stroke, and multi-point injection system SI engine, placed on a chassis dynamometer. Engine specifications are shown in Table 2. In the experimental study, the tests were performed at 900, 1300, 1800, 2400 and 2900 rpm and at stoichiometric air fuel ratio given MBT (Maximum Brake Torque timing) and at full open throttle (WOT).

Table 2: Engine specification.

Maker	Maruti
Engine type	3 cylinder, SI, Four stroke
Compression ratio	8.7:1
Bore	69mm
Stroke	74mm
Power	11kw, 3200 rpm
Loading	Eddy current dynamometer

The test fuels were gasoline and gasoline ethanol blends E5, E10, E15 and E20, the numbers following E indicate percentage of volumetric amount of ethanol. The purity ratio of ethanol is 99.5%. The properties of the various blends are shown in the Table 1. [16-19].

III. RESULTS AND DISCUSSIONS

A. Brake thermal efficiency

The effect of ethanol–gasoline blends on brake thermal efficiency is shown in Figure 1. The maximum BTH was found at full load with 1800rpm in E5 blend out of all blends. As E% increases in the fuel blend, the pressure and temperature decrease at the beginning of combustion. However, increasing E% increases the air–fuel ratio, i.e., decreases the heat transfer to the cylinder walls due to incomplete combustion, and therefore, increases the value of maximum pressure. It was found that at E5 and E10 blend gives higher BTH at all speeds as compared to gasoline, E10 and E20.

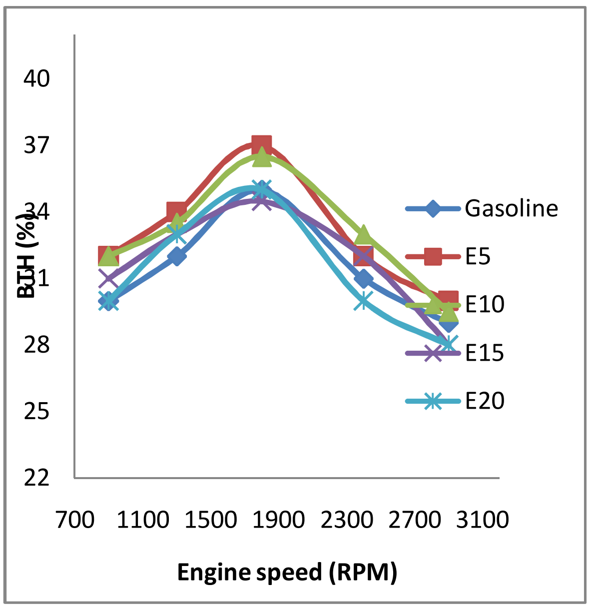

Fig. 1. Brake thermal efficiency vs. engine speed.

Brake specific fuel consumption. The effects of ethanol–gasoline blends on brake specific fuel consumption vs. engine speed are shown in Figure 2. As shown in this figure, the BSFC decreases as the E% increases up to 10%. On the other hand, as the engine speed increases upto 1800 rpm, the BSFC decreases. This is due to the increase in brake thermal efficiency and decreases in equivalence air fuel ratio (φ). Further, increase in engine speed results in increasing BSFC, since the brake thermal efficiency decreases and air fuel ratio (φ) increases. It is clear from figure that in case of E5 and E10 the lower BSFC was observed as compared to gasoline, E15 and E20.

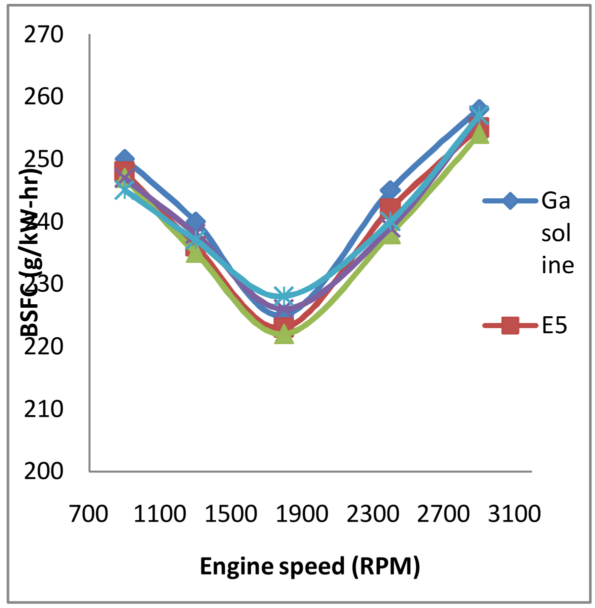

Fig. 2. Brake specific fuel consumption vs. engine speed.

Brake Torque. The effect of ethanol–unleaded gasoline blends on brake torque is shown in Figure 3. It is clear in figure that brake torque increases as the E% increases upto 1800 rpm engine speeds. The increase of ethanol addition to gasoline decreases its heating value, the increase in torque and power were obtained. Added ethanol will produce lean mixture that increases the relative air-fuel ratio (λ) to a higher value and makes the burning more efficient and improved anti-knock behavior (due to the addition ethanol, which raised the octane number) allowed a more advanced timing that result in higher combustion pressure and thus higher torques.

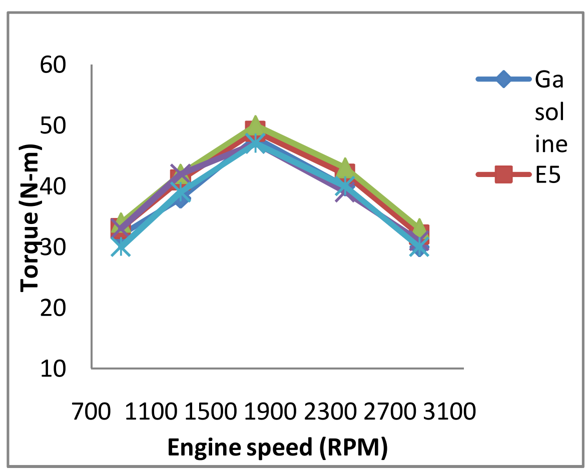

Fig. 3. Brake torque vs. engine speed.

It is clear from figure that E5 and E10 blend shows highest Brake Torque as compared to gasoline, E15 and E20.

B. Engine emissions

Carbon dioxide. Figure 4 represents the variation of carbon dioxide vs. engine speed. It is clear from figure that the CO_2 concentration decreases as the ethanol percentage increased. CO_2 emissions depend on relative air-fuel ratio. It was found that in case of E5 and E10 the CO_2 concentration was 9% and 9.5% at 2800 rpm as compared to gasoline was 10%. Further, addition of ethanol percentage results increase in CO_2.

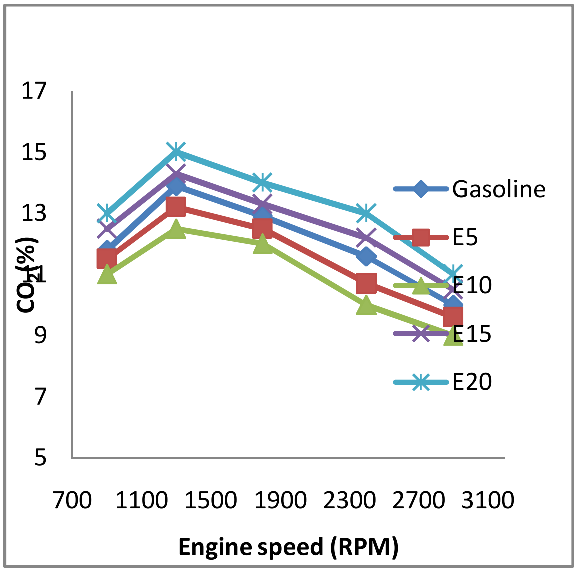

Fig. 4. Carbon dioxide vs. engine speed.

Carbon monoxide. Figure 5 represents the carbon monoxide vs. engine speed. It is clear from figure that the CO concentrations decreased with ethanol percentage increased. Thus, indicating that as the engine speed increases more incomplete combustion take place in case of gasoline as compared to ethanol blend. It was found that at 2800rpm, in case of gasoline the CO emission was 2.7% where as in case of E5 and E10 was 2.6% and 2.7% respectively.

Hydrocarbon. Figure 6 represents the hydrocarbon vs. engine speed. it is clear from the figure that HC emission was reduced with increasing speed. Further, with increasing percentage of ethanol in gasoline results reduced HC emissions. The concentration of HC emission decreases with the increase of the relative air-fuel ratio. The air–fuel mixing in case of ethanol blend enhances the combustion and complete combustion take place which result lower HC concentration. It was found that in case of E20 118 ppm as compared to gasoline was 130ppm.

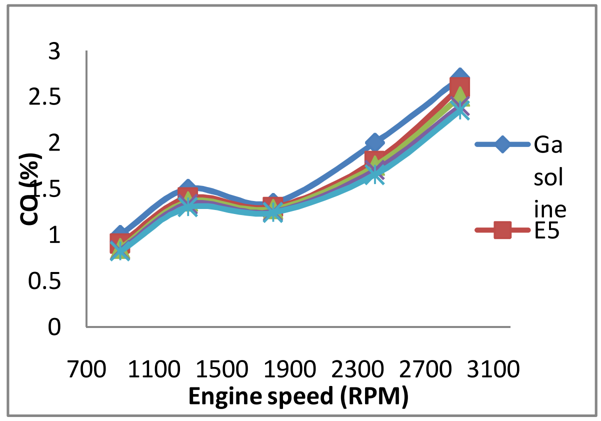

Fig. 5. Carbon monoxide vs. engine speed.

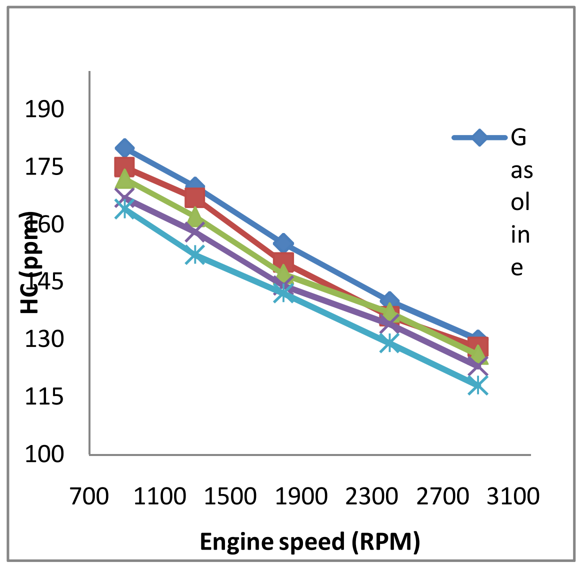

Fig. 6. Hydrocarbon vs. engine speed.

Oxides of nitrogen. Figure7 represents the oxides of nitrogen vs. engine speed. Nitric oxide levels mainly depend on the peak temperatures (>1500 °C) achieved during combustion and oxygen concentration. NOx emissions peak at slightly lean mixtures ($\lambda > 1$). The high heat of vaporization of ethanol lowers the flame temperature and this, in turn, results in lower NOx emissions. So, the NOx emission may change depending on the percentage of ethanol in the blend and operating conditions. Oxygen concentration and combustion temperature and time are the main parameters affecting the NOx emissions. It was found that in case of gasoline higher NOx level was 1450ppm observed as compared to other blends.

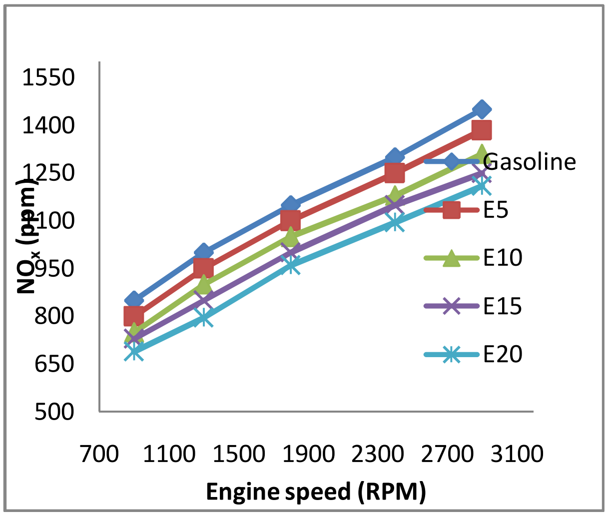

Fig. 7. Oxides of nitrogen vs. engine speed.

IV. CONCLUSIONS

Ethanol's physical and chemical properties show that it can be used as an alternative fuel or additive in SI engine. Ethanol-gasoline blends show very effective results. In this study, four different blends E5, E10, E15 and E20 were run on SI engine for analyzing performances and emissions. It was found that E5 and E10 blend was most effective blend they improved performance and reduced emissions. It was concluded that E5 and E10 blend improved brake thermal efficiency, brake torque reduced brake specific fuel consumption as compared to gasoline. Further both blends also reduced emissions like CO_2, CO, HC and NOx as compared to gasoline.

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