Technical Assessment of Performance & Emission Characteristics of an SI Engine using Ethanol - Gasoline Blended Fuel

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***Abstract*— Amongst alcohols, ethyl alcohol exhibits good burning characteristics due to which it is going to be use as additive in the spark ignition engines around the world. Alcohols have high octane rating and contain oxygen as compare to gasoline. Due to which the knocking tendency reduces which leads in the reduction of some exhaust emission such as CO (carbon monoxide). In this study, ethyl alcohol, an oxygenated fuel, was considered as a gasoline fuel additive. The experimental analysis of ethyl alcohol blended fuels with various blending rates (10, 20 and 30 percent by volume) on engine performance and exhaust emission were investigated using a four cylinder, four stroke spark ignition MPFI engine. The result showed that blending of ethanol with gasoline increase the brake thermal efficiency, brake specific fuel consumption and reduction in exhaust gas temperature. The exhaust emissions of carbon monoxide and hydrocarbon were found to be lower while the nitrogen oxide emission was high.**

Keywords*— Additive, Brake thermal efficiency, Ethanol, Exhaust emission, Exhaust gas temperature, Performance

I. INTRODUCTION

The conventional energy resources are decreasing at a very higher rate because of its limited availability in the earth. For meeting the energy demand of the people, the unconventional energy resources are being the replacement of the conventional energy resources. Alternative fuels are best resources of power generation in internal combustion engine. Since the emission generated by the conventional fuel like gasoline, diesel are very harmful as compare to alternative fuel like alcohols. Ethanol is being used in many countries as clean fuel in the internal combustion engine.

Many researchers reported that addition of ethanol as a fuel additive to gasoline causes an improvement in engine performance and exhaust emissions. The addition of ethanol in the blend improves the brake power, brake thermal efficiency, volumetric efficiency, while bsfc, CO and HC emission decreases [1]. The effects of ethanol- gasoline blends on spark ignition engine performance and emissions were investigated by Hseih et al. [2]. In this study, he found that using ethanol-gasoline blended fuel, torque output and fuel consumption increased. CO and HC emissions decrease while CO_2 emission found to be increased.

Celik investigated [3] the effect of ethanol-gasoline fuels on power and specific fuel consumption (SFC). As the ethanol content in the blend fuel increase, power slightly increases. When compared to gasoline fuel, the power increases for all the fuel blends. The heat of evaporation of ethanol is higher than that of gasoline. High heat of evaporation can provide fuel-air charge to cool and density to increase, thus higher power output is obtained to some extent. However, power increase starts to decrease when ethanol content is raised to more than 50 percent. Yüksel et al. [4] investigated the effect of gasoline (E0) and gasoline-ethanol blends on the performance of SI engine. The result showed that using the blend fuel, an increase in the specific fuel consumption and a decrease in the engine torque and power output was found. Although thermal efficiency showed no significant change relative to gasoline, the advantage of increase in octane number could well be used in increasing the efficiency when the compression ratio of the engine was changed.

Koç et al. [5] experimentally studied the effects of unleaded gasoline and unleaded gasoline-ethanol blends (E50 and E85) on engine performance and concluded that addition of ethanol to unleaded gasoline leads to increase the engine torque, power and fuel consumption and decrease carbon monoxide, nitrogen oxide and hydrocarbon emissions. Hasan [6] investigated the effect of ethanol- unleaded gasoline fuel blends on the performance of an SI engine. The results revealed that when ethanol blended gasoline fuel was used, brake power, brake thermal efficiency and volumetric efficiency increased while brake specific fuel consumption and air-fuel ratio decreased. Yücesu et al. [7] tested experimentally the engine performance and emission at different compression ratios of spark ignition engine, using ethanol-gasoline blend fuels in the volumetric ratios of 0-30 percent. The result showed that at high compression ratio the torque output did not change noticeably. The CO and HC emission also found to be decreased.

Fikert et al. [8] studied the behavior of dual fuel system which could be serviceable by making simple modifications would not cause complications in the carburetor system. The carburetor was redesigned to use gasoline-ethanol mixture as a fuel. The result showed that torque output and bsfc increased marginally while the CO and HC emissions decreased significantly. He et al. [9] reported the behavior of ethanol-gasoline blends on emissions and catalyst conversion efficiencies in spark ignition engine. The result showed that the carbon monoxide, hydrocarbon and nitrogen oxide emissions were found to be decreased by using ethanol-gasoline blends. Costa et al. [10] tested the performance of a spark ignition engine on hydrous ethanol and anhydrous ethanol at variable compression ratio. Engine torque, BMEP and output power are improved with increased compression ratios at high speeds for both, hydrous and anhydrous ethanol. As compression ratio increased, specific fuel consumption decreased while the brake thermal efficiency and exhaust gas temperature increased for hydrous ethanol. At low compression ratio, volumetric efficiency decreased for hydrous ethanol. It was also found that the use of hydrous ethanol decreased CO and HC emission but increased CO_2 and NO_x levels.

Varol.V et al. [11] investigated the behavior of methanol, ethanol and butanol on a spark ignition engine. It was found that brake specific fuel consumption was higher for methanol, ethanol and butanol in comparison to unleaded gasoline. Amongst all blends, methanol shows high value of bsfc. The brake thermal efficiency increases with an increase in engine speed, for E10 and M10, the average brake thermal efficiency was about 4.5 -6.8 percent lower as compared to unleaded gasoline while for B10 it was about 2.8 percent lower E10 shown the low value of carbon monoxide emission and higher value of HC emission in comparison to B10 and M10. Canacki et al. [12] investigated the emission values of ethanol-gasoline and methanol-gasoline blends in a spark ignition engine. At all wheel power at the speed of 80km/h, the value of carbon monoxide, carbon dioxide, hydrocarbon and nitrogen oxide were found to be decreased for ethanol-gasoline or methanol-gasoline blended fuel.

Al-Hassan.M et al. [13] investigated the performance of a Diesel engine fueled with Diesel Biodiesel - Ethanol blends. Their experimental results revealed that the equivalence air-fuel ratio and the brake specific fuel consumption for the fuel blends are higher than that of diesel fuel and increases with the increase of the ethanol concentration in the blends. The brake power for the fuel blend of 5 percentethanol concentration is close to that of diesel fuel and decreases with higher concentrations. The brake thermal efficiency was increased with fuel blends of 5 and 10 percent ethanol concentration and decreases with a higher ethanol proportion in the blends. In conclusion, among the different fuel blends, the blends containing 5 percent and 10 percent ethanol concentration are the most suited for CI engines due to its acceptable engine performance and to the fuels solubility. Salhab.Z et al. [14] investigated the performance properties of spark ignited outboard engine powered by gasoline and LPG. They reported that with the use of injected LPG reduced the engine torque, brake power and brake specific fuel consumption compared to gasoline, while for vacuum system are higher except brake power.

II. MATERIALS AND METHODS

A Multi Port Fuel Injection type four cylinder, water cooled four stroke SI engine of Hindustan Motor make, was selected for the study. The technical specification of the engine is listed in Table I. An eddy current dynamometer was connected to the engine. For measuring the torque a strain-gauge based load cell is attached with dynamometer. For measuring the pressure inside the cylinder, a piezoelectric type pressure sensor (Quartz) was flush mounted on to the cylinder head. The flow rate of air was measured by using an air tank filled with differential pressure transmitter. Output shaft of the engine is coupled with crank angle sensor for detecting crank angle and rpm of the shaft. The real time data acquisition can be done by interfacing the set up with computer using software. The experimental set up is installed in the I.C.Engine lab of Mechanical Engineering Department of GBPUA&T, Pantnagar, India. The schematic illustration of the experimental set-up is shown in Figure 1.

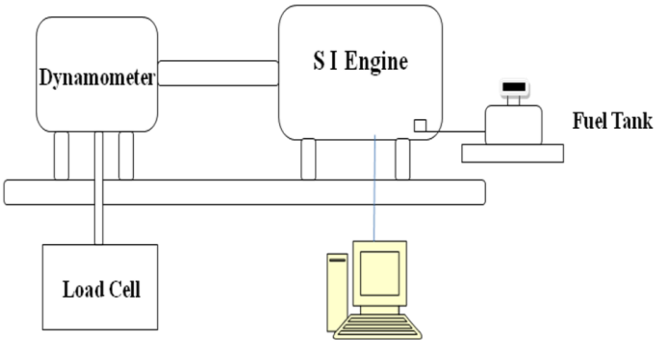

Fig. 1 Schematic diagram of experimental set up

Experiments were conducted on base engine (without any modification) with gasoline and ethanol–gasoline fuel blends for benchmarking. Carbon monoxide, hydrocarbon and NO_x were measured by using INDUS 5 gas analyzer. Initially the engine was allowed to warm up for a period of 15-20 min by starting. The new fuel blends were using for the experiment when the earlier fuel blends was totally consumed.

TABLE I. SPECIFICATIONS OF THE EXPERIMENTAL ENGINE

Items	Specification
Make/Model	Hindustan Motors/ Ambassador
Number of cylinder	4
Bore/Stroke (mm)	84/82
Compression ratio	8.5:1
Displacement volume (cc)	1817
Cooling system	Water Cooled

In the present work, engine performance and emission of three ethanol- gasoline blends and gasoline were experimentally investigated. Experiment was performed at five varying engine speeds (1000, 1500, 2000, 2500 and 3000 rpm) and the desired engine speed was maintained by the load adjustment for all fuels. The calculated values of densities and calorific values of the fuels are shown in the Table II.

TABLE II. CALCULATED PROPERTIES OF TESTED FUELS

Fuel Type	elative Density	orific Value (Mj/Kg)
Gasoline	0.730	42.95
E10	0.736	41.36
E20	0.741	39.77
E30	0.747	38.20

III. RESULT AND DISCUSSION

The addition of ethanol to gasoline on spark ignition engine performance and exhaust emission at different engine speed were investigated experimentally.

The variation in brake specific fuel consumption with engine speed is shown in fig.2. As the engine speed is increasing, the brake specific fuel consumption is decreasing. Since ethanol-gasoline blends have lower calorific value in comparison to gasoline so their bsfc is higher relative to gasoline. All fuel blends are showing increase in bsfc as compare to gasoline. Increase in bsfc indicates that for maintaining the same power output, the engine required more fuel. The minimum bsfc was observed with gasoline as 0.367 kg/.kW-h which is 17.5, 15 and 18.44 percent lower than E10, E20 and E30 blends at the engine speed of 2500 rpm.

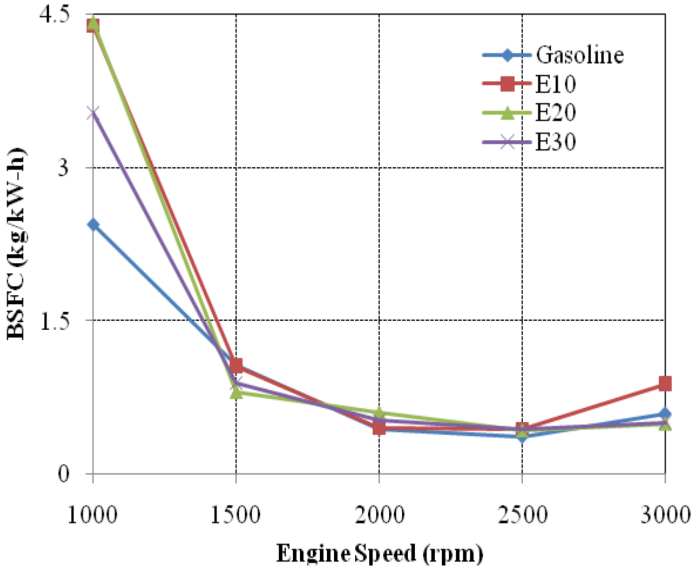

Fig.2. Variation of brake specific fuel consumption with engine speed on ethanol blends

The variation in BTE at varying engine speed is shown in the fig.3. The brake thermal efficiency is found to be higher for all fuel blends as compare to gasoline. Since ethanol contains about 35 percent oxygen by wt, which helps in proper combustion inside the engine cylinder. The sole blended fuel burns in the cylinder due to high latent heat of vaporization of ethanol. As the cylinder temperature is high during the operation due to which fuel vaporize earlier by absorbing the heat. This situation decreases the necessary work requirement for compressing the air-fuel mixture thus leads to increase in brake thermal efficiency of the engine. It is observed that BTE of E30 is 5.30 percent higher at 2500 rpm in comparison to gasoline.

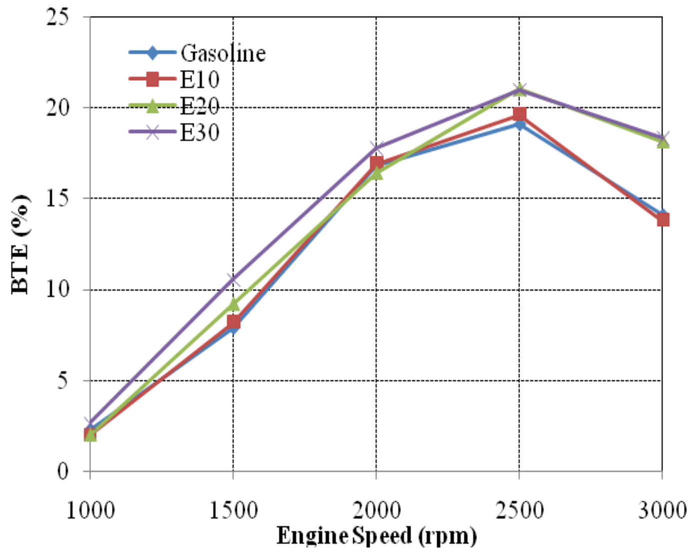

Fig.3. Variation of brake thermal efficiency with engine speed on ethanol blends

The variation in exhaust gas temperature with the engine speed is shown in the fig. 4. All the blends showing the reduction in EGT at higher engine speed as comparison to gasoline. Ethanol exhibits high latent heat of vaporization with respect to gasoline due to which there is a drop in temperature of the charge during the closing of intake valve. The temperature at the end of compression stroke decreases which leads to the low value of exhaust gas temperature at the end of combustion of fuel. E 30 is showing maximum reduction in the EGT at higher engine speed in comparison to gasoline.

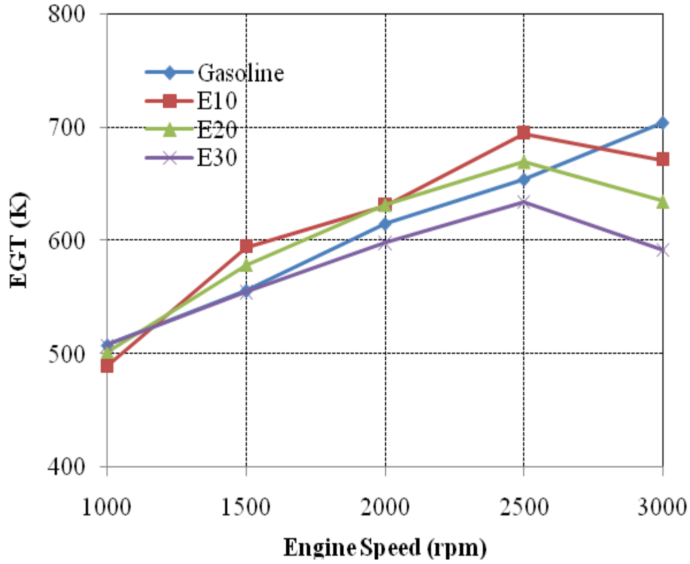

Fig.4. Variation of exhaust gas temperature with engine speed on ethanol blends

The engine exhaust emissions were measured by using 5 gas analyzer at different engine speeds. Measurement of all regulated pollutants like HC, CO and NO_x was done for all fuel blends and gasoline.

The effect engine speed on CO emission is shown in the fig.5. As the engine speed increases, the value of CO remains constant. This is due to fact that spark ignition engine generally run on rich mixture due to which the CO emission found to be present because of poor combustion inside the cylinder. CO emission found to be lower for ethanol-gasoline blends compared to gasoline. This is due to the fact that ethanol contain oxygen molecule which helps in proper combustion of the fuel inside the cylinder because of leaning effect. The minimum CO concentration was found with E20 blends. The maximum mean reduction of CO emission was found with E20, which is 50.1 percent lower than gasoline.

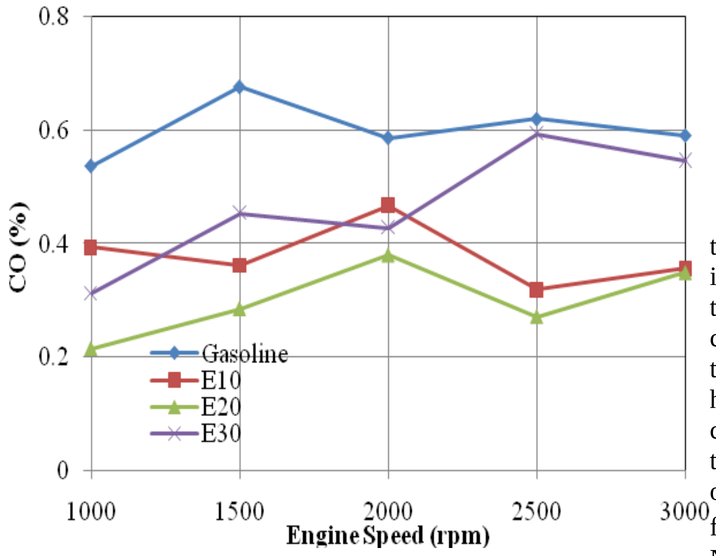

Fig.5. Variation of CO emission with engine speed on ethanol blends

The effect of engine speed in the blend fuel on the HC emissions is shown in the fig.6. HC emissions occur due to the incomplete combustion and low temperature inside the cylinder. With the increase in engine speed, the flame velocity of the mixture increases as well as the turbulence inside the cylinder also increases which leads to the increase in temperature inside the cylinder. All the blends are showing the decreasing trend with the increasing speed. HC emission of E20 was found to be slightly higher in comparison to gasoline. The minimum CO concentration was found with E20 blends. The maximum mean reduction of HC emission was found with E20, which is 50.3 percent lower than gasoline.

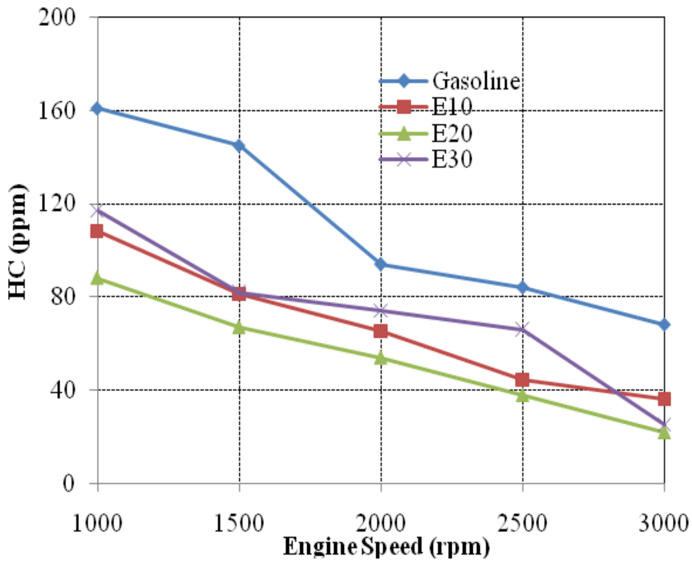

Fig.6. Variation of HC emission with engine speed on ethanol blends

Fig.7 depicts the behavior of the NO_x formation with the engine speed. It can be seen that as the engine speed increases, NO_x emissions of the fuel blends also increases. As the engine speed increases, the temperature inside the cylinder increases due to increase in turbulence and that leads to the increase in NO_x emission. Another reason is that at higher engine speed, the rich mixture required by the cylinder. Since the use of oxygenated fuel in the engine leads to make the air-fuel mixture lean due to more availability of oxygen contents which leads to increment in the NO_x formation inside the cylinder. All blends are showing higher NO_x formation in comparison to gasoline due to very lower amount of oxygen availability in gasoline.

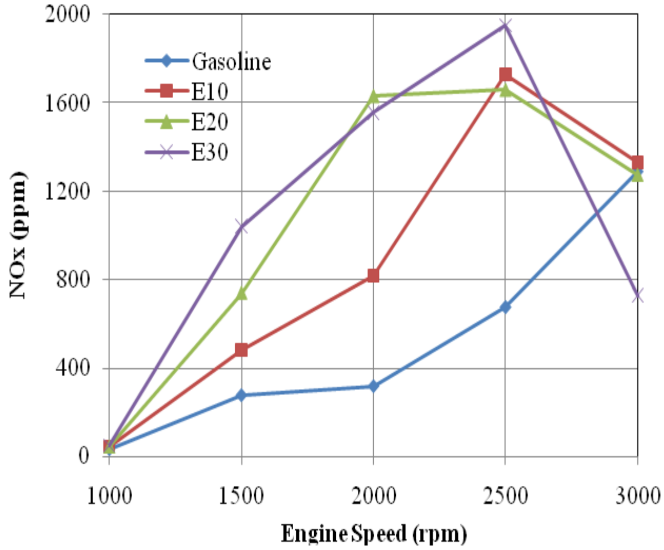

Fig.7. Variation of oxides of nitrogen emission with engine speed on ethanol blends

IV. CONCLUSIONS

Conclusion can be drawn based on the SI engine performance and emission characteristics of ethanol-gasoline blends and gasoline in a multi cylinder spark ignition MPFI engine without any modification in the engine at various engine speeds. The result may conclude as:

- The use of ethanol as a fuel additive to gasoline causes in the improvement in engine performance and exhaust emissions.
- Since ethanol has lower calorific value so the brake specific fuel consumption of the ethanol-gasoline blends are found to be higher than gasoline.
- Brake thermal efficiency of the ethanol-gasoline blends is found to be higher in comparison to gasoline.
- Due to oxygen contain by ethanol-gasoline blends, the exhaust gas temperature of the blends are found to be lower in comparison to gasoline.
- Ethanol-gasoline blends produced higher emission of NO_x in comparison to gasoline.
- HC and CO emissions for E20 were found to be lower in comparison to gasoline.
- All the tested fuel performed well in the engine without any hardware modification.

Overall, it can be concluded that the existing fleet of automobiles showing better performance without any modifications in engines especially in country like India, where ethanol blending has been promoted by the Government but no instruction given to the automobile industries regarding the material compatibility in engines with ethanol-gasoline blend.

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