PERFORMANCE AND EMISSION CHARACTERISTICS OF GASOLINE-ETHANOL BLENDS ON PFI-SI ENGINE

D. Vinay Kumar¹, G. Samhita Priyadarsini², V. Jagadeesh Babu³, Y. Sai Varun Teja⁴

¹,²,³,⁴ Department of Mechanical Engineering, Vignan’s Foundation for Science Technology and Research, Guntur, Andhra Pradesh, India

Corresponding Author: D. Vinay Kumar
E mail: vnykmr.d@gmail.com

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Abstract

Alcohol based fuels can be produced from renewable energy sources and has the potential to reduce pollutant emissions due to their oxygenated nature. Lighter alcohols like ethanol and methanol are easily miscible with gasoline and by blending alcohols with gasoline; a part of conventional fuel can be replaced while contributing to fuel economy. Several researchers tested various ethanol blends on different engine test rigs and identified ethanol as one of the most promising ecofriendly fuels for spark ignition engine. Its properties: high octane number, high latent heat of vaporization give better performance characteristics and reduces exhaust emissions compared to gasoline. This paper focuses on studying the effects of blending 50% of ethanol by volume with gasoline as it hardly needs engine modifications. Gasoline (E0) and E50 fuels were investigated experimentally on single-cylinder, four-stroke port fuel injection spark ignition engine by varying engine speed from 1500 rpm to 3500 rpm. Performance Characteristics like torque, brake power, specific fuel consumption, and volumetric efficiency and exhaust emissions such as HC, CO, CO₂, NOx were studied.

Keywords: Ethanol, Emissions, Gasoline, Port fuel Injection

I. Introduction

Biofuels have gained global attention to improve the air quality and energy security of different nations as they can be used as alternatives to fossil fuels. As the existing energy infrastructure is compatible to run biofuels or its fossil fuel blends with little or no modifications, Governments across the world introduced various policy measures like fuel blending programmes, incentives for flex fuel vehicles to ensure protection from volatile prices global crude oil market. Government of India introduced Ethanol blending program in 2003 and invested INR 7000 crores in 2015-16 to support second generation biofuels processing and production to generate 350 million liters of ethanol by 2019. In order to shift towards an economy based on

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biofuels lot of research is being carried out by several researchers. Efemwenkiekie U.K [III] 2019 investigated the performance of E0, E1, E3, and E5 on Cusson P8160 single cylinder 4-stroke direct injection engine. It is reported that E3 has highest performance characteristics among the tested blends resulting in the increase of brake thermal efficiency, brake power and decrease in specific fuel consumption at full load condition. Ripudaman Singh 2019 [VI] critically focused on the effect of single and multiple injection strategies of particulate emissions, engine efficiency of gasoline-ethanol blends. Mercedes2.0 L 4-cylinder, in-line turbocharged gasoline direct injection engine with Bosch piezo electric fuel injectors was used to test fuel blends of E0,E30, E85 in 4 injection events. Spark timings were adjusted to maximum brake torque condition for each injection strategy that was tested. It was reported that the triple injection strategy reduced PN emissions for all the tested samples and it was more effective in case of ethanol blends. Injection timing and fuel mass in each injection plays vital role in engine performance, due to shorter ignition duration fuel mass injected also decreased. E85 resulted in reduction of 90%, 50% THC, 30% in CO emissions. I.G.G Badrawad 2019 [I] considered E0, E5,, E10,E15 blends and studied their effect on 4-stroke single cylinder motorcycle engine at different engine speeds of 4000,5000,6000,7000,9000 rpm. It is observed that brake power decreases for all blends at 9000 rpm,E15 has maximum brake power at 8000rpm.HC,CO decline at the rate of 0.11 %,7ppm with E10 at 8000 rpm respectively. At 8000-9000 rpm more heat lost to surroundings and lower power is developed for E15. M.Mourad 2019 [VI] used Hyundai G4en 4-cylinder water cooled port fuel injection SI engine using ethanol/butanol, gasoline blends .EB2, EB5, EB10, and EB15 were tested at different engine speeds from 1000-3400rpm, EB15 fuel blend gave best performance characteristics with reduced HC, CO emissions.

E.Galloni et.al 2018 [IV] studied the performance characteristics of gasoline –alcohol blends on 4-cylinder turbocharged port fuel injected spark ignition engine with compression ratio at 9.8:1 at maximum load conditions. Alcohols such as ethanol and butanol were blended with gasoline in different proportions to a maximum of 10% and 40% by volume respectively. It is reported that efficiency increases by 3% due to increase in oxygen content. At maximum load, spark timing advances due to knock resistance of alcohols. For binary, ternary mixtures of gasoline, ethanol and butanol CO2 reduction is around 8% and NOx emissions were reduced to lower maximum temperature in combustion chamber.

Hasan et.al 2018 [V] investigated the influence of various compression ratios on engine performance, exhaust emissions with E10, E20 blends on 4-stroke single cylinder air-cooled engine. Alcohol fuels have higher stoichiometric flame speed which promotes faster and complete combustion .Due to this phenomenon improved volumetric efficiency and brake thermal efficiency were noticed. Varying Compression ratio has affected bmep by 12 % for E10. BSFC increased by 4%, 46% for E10, E20 respectively. BTE -16% low load, 12 % high load conditions. HC & CO higher for larger compression ratios, lowest NOx for E20, highest heat of evaporation.

Battal Dogan 2017 [VIII] tested E0, E10, E20, E30 blends on four cylinder four stroke SI engine at full load condition under different speeds through exergy analysis.
and reported that the highest efficiency is observed at 3000 rpm on an average. Highest engine torque was noticed between 2500 rpm-3000 rpm for all the tested fuels, lowest fuel consumption is reported at 3000 rpm for E 30.

Experimental Setup

Experiments were performed on Honda Gx 200 four stroke single cylinder, variable speed, air cooled, port fuel injection spark ignition engine. The setup is connected to water cooled eddy current dynamometer and has standalone panel box with fuel tank, manometer, fuel measuring unit, and transmitter for air and fuel flow measurement, temperature indicator and load indicator. The technical specifications are listed in Table 1

The engine must be connected to Computerized ECU system and water flow through engine pipelines must be ensured before starting. Adjust required speed and load using the throttle knob and dynamometer loading unit respectively. The exhaust gases were measured with the help of AVL gas analyzer. Gasoline and Ethanol were used as base fuels. Experiment was carried out with neat gasoline and gasoline-ethanol blend.

Table 1: Engine Specifications

| Engine Model       | Honda GX                  |
|--------------------|---------------------------|
| Engine Type        | Four Stroke SI engine     |
| No.ofCylinder      | 1                         |
| CompressionRatio   | 8.5:1                     |
| Bore               | 68 mm                     |
| Stroke             | 54 mm                     |
| Maximum Power      | 4.1KW@ 3600 rpm           |
| Connectingrod length | 105 mm                   |
| Displacement       | 196.11 cc                 |

In the present experiment ethanol was blended with gasoline on volume basis. Ethanol by 50% volume was blended with 50% gasoline; this blend was called E50. Gasoline is designated as E0 as it doesn’t contain any ethanol by volume. Fuel blends were prepared at the time of experimentation to maintain uniformity of fuel mixture and to avoid further reactions between alcohols with water vapor. The properties of Gasoline and Ethanol are listed in Table 2.
Table II: Properties of fuels [VII]

| Property                        | Gasoline | Ethanol   |
|---------------------------------|----------|-----------|
| Chemical formula                | C₅₋C₁₂  | C₂H₅OH   |
| Molecular weight                | 87.4     | 46.07     |
| Density                         | 750-765  | 785-809.9 |
| Stoichiometric air-fuel ratio   | 14.2-15.1| 8.97      |
| Research octane number          | 91-100   | 108.1-110 |
| Motor octane number             | 82-92    | 92        |
| Lower heating value             | 44       | 26.9      |

Results and Discussions

Experiments were performed at different engine speeds of 1700 rpm, 2100, 2500, 2900, 3300 rpm on partial load of 5kg and partly open throttle position. Figure 1 shows the variation of brake power for the fuel blends E50 and E0. Maximum brake power of 2.56kw is recorded for E0 and lowest for E50 at 1700 rpm. Similarly Fig. 2 shows variation of torque and it is found that torque decreases with increase in engine speed after it reached a maximum. Higher torque of 7.98 Nm occurred at for E0 and lowest 7.49 Nm for E50 at 2000rpm. Gasoline-Ethanol blends have lower thermal values due to which torque decreases and also affects engine power. Figure 3 shows the variation of volumetric efficiency, volumetric efficiency is highest at 3300rpm for E50 and least at 1756 rpm for E50.

Fig. 1: Brake Power Vs Engine speed
Fig. 2: Torque Vs Engine Speed

Fig. 3: Change in Volumetric efficiency

Fig. 4: Brake Thermal Efficiency Vs Engine Speed
Ethanol has the characteristics of high evaporative cooling. This property results in cooler intake process, more air enters into combustion chamber, density of air increases and raises volumetric efficiency. This requires less work input at compression stroke. Figure 4 shows that there is an improvement of 39.73% in brake thermal efficiency for E50 compared to gasoline, change in specific fuel consumption at different engine speeds is shown in figure 5. It was measured that specific fuel consumption of E50 is more after 2500 rpm. Latent heat of ethanol is more compared to gasoline. When ethanol is added to gasoline, the latent heat of vaporization of new fuel blend increases and also increases fuel intake into the combustion chamber during compression stroke. As engine speed increases homogeneity of fuel mixture increases and causes combustion more efficiently reducing heat loss to the cylinder walls.

B. Emission Characteristics

Hydrocarbon emissions occur due to unburnt fuel residues. Figure 6 shows variation of Hydrocarbon emissions for the blends E0 and E50. Hydrocarbon emissions decreases as engine speed increases for all the fuels. When engine speed increases, homogeneity of the mixture inside the cylinder also increases and promotes complete combustion. This phenomenon results in decreasing tendency of HC emissions. When ethanol is added, oxygen content inside the cylinder increases, higher HC emissions are recorded at 783ppm at 1700 rpm for E50 and lower for E0 at 3300 rpm. Figure 7 shows variation between CO emissions of E0 and E50 blends. In the experiments conducted highest CO emissions are recorded for E0 at 1700 rpm and lower at 2900 rpm for E50. Blending of ethanol with gasoline promotes cleaner combustion due to the presence of oxygen in its chemical structure and due to its evaporation characteristics.
Fig. 6: Change in Hydrocarbon emissions with engine speed

Fig. 7: Change in Carbonmonoxide emissions with engine speed

Fig. 8: Change in Carbon dioxide emissions with engine speed
As ethanol content in the fuel blend increases, CO emissions decreases. Combustion of hydrocarbon fuels causes CO2 emission and Increase in CO2 emissions indicates complete combustion of fuel inside the cylinder. Figure 8 gives lowest CO2 emissions at 2900 rpm for E50 fuel and highest to E0 at 2500 rpm. From figure 8 it is clear that addition of 50% of ethanol by volume can reduce carbon dioxide emissions it is found that CO2 emissions reduced at all speeds considered. This is due to consumption of less air. When combustion equations are considered, ethanol blend requires less amount of air to burn. Figure 9 shows variation of NOx emissions. NOx emissions were drastically reduced for E50 at 3300rpm and recorded highest for E0 at 2500 rpm. Decrease in emissions is due to high evaporation of ethanol. It lowers the temperature of the blend and ethanol blended fuels need less air for combustion.

**IV. Conclusion**

In this experimental investigation, the performance and emission characteristics of E0 and E50 fuel blend was studied on port fuel injection SI engine. The investigation was carried out without any modifications to the engine. Results obtained clearly shows that brake thermal efficiency improved by 39.47%. Volumetric efficiency increased by 20% with E50 fuel blend. Emission levels of E50 were considerably less compared to E0. CO, CO2, NOx levels were reduced though there was a slight increase in Hydrocarbon emissions.

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