

Investigation on Combustion, Performance and Emissions of Automotive Engine Fueled with Ethanol Blended Gasoline

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ABSTRACT

To tackle the problems associated with the volatility of crude oil prices and ever stringent emission norms, oil industries and automobiles manufacturers are experimenting with various alternative fuels to increase its percentage share in the energy mix and to reduce the vehicular emissions. Alcohols are preferred choice of alternative fuels for the gasoline engines as it does not require any major engine modification and new infrastructure for the fuel distribution network. Ethanol as sole fuel or blending component for gasoline for use in spark ignition engines has been investigated many decades. Currently, 10% ethanol is blended in motor gasoline in India and the ethanol concentration may be further increased in future. In order to study the effect of higher blends of ethanol (upto 20%) on engine in-cylinder combustion, performance and emission, investigations were carried out on a latest generation passenger car engine in a climatic controlled test cell. Engine combustion, performance and emissions were analyzed at full throttle condition at regular speed intervals. Higher octane number and oxygen in the ethanol blends improved the combustion and thereby increased the power and torque marginally. Ethanol blends reduced the specific energy consumption of the engine for the all speeds at full throttle opening. E20 blends decreased CO emission by 65%; HC emission by 38% with the penalty of doubling the NOx emission at rated power condition. Increase in combustion duration was observed with ethanol blends compared to gasoline. Indicated mean effective pressure and maximum peak pressure of the engine were increased with engine speed for the all test fuels and the ethanol blends increased these values marginally. Ethanol as blending component for gasoline improved the combustion and thereby marginally enhanced the engine performance and significantly reduced the exhaust emissions.

KEYWORDS: Gasoline, Ethanol, Combustion, Performance, Emissions

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INTRODUCTION

Energy is the prime mover for economic growth and development of any country. Economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and environmentally friendly as well. Petroleum oil, which is the most important and abundantly available energy source, is largely consumed in the World. However, the price of crude oil is very volatile and supply is driven by market price. Presently the world is confronted with twin crisis of fossil fuel depletion and environmental concern. Automobile manufacturers, oil industries, environmentalists and academics are putting more efforts to tackle these issues. The widely accepted solutions to tackle this problems are use of renewable alternative fuels, fuel cells, improvement in engine technologies and exhaust aftertreatment devices [1, 2].

Ethanol is an oxygenated fuel, produced from fermentation of biological renewable resources such as molasses, sugar cane or starch. N.A.Otto, the German inventor of the internal combustion engine, conceived his invention to run on ethanol. However, ethanol

utilization again picked up during fuel crises arising from the World War I&II in the 20th century [3]. The clean air act of 1970 allowed the Environmental Protection Agency (EPA) to set standards for vehicular emissions. This led to a requirement of oxygenated fuels to reduce the vehicular emissions from gasoline engines [4, 5, 6].

Gasoline powered vehicles emits lesser NOx and particulates compared to diesel powered vehicles. Ethanol's high octane number makes it attractive for use in gasoline engines. Ethanol and gasoline are fully miscible and have been blended together in a wide range of concentrations. Blend ratio of ethanol in gasoline is increasing over the years and currently the permitted amount of ethanol in gasoline in India is 10% [7]. If ethanol can be produced abundantly and economically, it will be an attractive alternative fuel for spark-ignition (SI) engines. It can be used either as neat fuel or as a gasoline blend. Both options provide some advantages for engine performance, fuel economy and exhaust emissions [3].

Gasoline is a mixture of hydrocarbons having different boiling points and it creates a typical distillation curve where ethanol has a single boiling point and blending of ethanol in gasoline would

cause changes in the distillation curve of gasoline (Appendix-I). Ethanol has a property of very low vapor pressure and when it is blended with gasoline, the resultant fuel blend can have a vapor pressure that is higher than the gasoline or ethanol alone. Reid vapor pressure (RVP) of gasoline and ethanol are 53.6 kPa and 16 kPa respectively. RVP of E5, E10 and E20 are 59.5, 61.4 and 59.9 KPa respectively (Appendix-I).

Ethanol is completely miscible with gasoline and even a small percentage of water in gasoline or ethanol leads to phase separation. Such separation can result in poor engine performance and damage to the engine [8]. Hence, it is necessary to ensure that ethanol to be blended with gasoline is anhydrous. Ethanol has higher research octane number (RON) (>100) than gasoline. When ethanol is blended with gasoline, the RON is boosted but there is minimal or no increase in motor octane number (MON) [3]. Auto-ignition temperature and flash point of ethanol are 423 °C and 13 °C respectively whereas 257°C and -43°C respectively for gasoline. This makes the ethanol as safer fuel for transportation and storage [3]. The latent heat of evaporation of ethanol is about 2.6 times higher than that of gasoline that leads to a reduction in the intake temperature in manifold and increases the volumetric efficiency [9]. Calorific value and density of the blends are linear relationship while octane number and vapor pressure of the blends is non-linear [5]. Calorific value of ethanol is lower than that of gasoline and hence more ethanol is required to achieve the same energy output. Since the ethanol itself contains oxygen molecules, the amount of air required for complete combustion is lesser for alcohol. The stoichiometric air-fuel ratio (AFR) of alcohol is about 9 as compared to gasoline 14.7. Since ethanol is biodegradable and distilled from biomasses, it can be considered as a renewable energy source. Ethanol can be used in majority of gasoline vehicles without the need for major engine fuel system modifications. Thus the ethanol has become oxygenated fuel for the countries like Brazil, USA, and India etc. [3].

Pleanjai et al. conducted chassis dynamometer studies on two wheelers using E10 and E85 blends and reported that the THC emissions from E85 reduced by 4-60% (average 43%) compared with those of gasoline fuels and CO emissions also showed a reduction by 40-95% (on average 75%) [10]. Studying the fuel composition effects on combustion parameters is important as it has direct impact on engine performance and emissions as well. It has been reported by many researchers that the combustion parameters varied from cycle by cycle and these are due to variations of spark discharge characteristics; variations of in-cylinder mixture (overall fuel/air ratio and fraction of diluents); spatial mixture in homogeneity at spark plug; variations of turbulence intensity; variations of mean flow speed and direction in the spark plug vicinity and variations of overall in-cylinder flow pattern [11, 12].

Many researchers had investigated the effect of blending of ethanol on carbureted gasoline engine's performance and emissions but a few papers only reported the ethanol-gasoline blends on a latest generation multi point fuel injection (MPFI) technology engine for its performance and emissions. Moreover, very limited investigations have been carried out to study the

combustion behavior of the ethanol-gasoline blends on a MPFI bifuel engine. Hence, in this scenario, it is imperative to study the effect of ethanol blended gasoline on MPFI engine combustion, performance and emissions.

The objective of this paper is to investigate the effect of ethanol blended gasoline (up to 20%) on a latest generation passenger car spark ignition engine for its combustion, performance and exhaust emissions characteristics.

EXPERIMENTAL SETUP

The engine transient dynamometer test bench is installed in a climate controlled test cell which is capable of maintaining the test cell temperature ranges between -5 to +45 °C. The test bench consists of a 4 cylinder, MPFI gasoline engine, 120 kW asynchronous dynamometer and fluid conditioning systems, and gas emission measuring equipment. Schematic of the test facility is shown in Figure 1 and test engine specification is given in Table 1. AVL Puma Open 5.0 test bed automation system controls the dynamometer, fluid controlling systems and emission measuring equipment which is interfaced with the engine test bed. The test cycles are programmed in the Puma for the automatic operation of test run. A combustion air system is located in the plant room adjacent to the test cell and consists of an AVL ACS1200 unit and an air dryer to reduce the humidity of the incoming air. The controlled temperature air is enters the engine intake system through the ABB make air mass measuring equipment. The system is equipped with a coolant and oil temperature control systems that is capable of maintaining the coolant temperature of 70 to 120°C and oil temperature of 70 to 140 °C. Fuel metering is performed by the AVL735S, which utilizes the Coriolis principle to measure mass flow of fuel consumed by the engine. The AVL 753C fuel temperature conditioning system is capable of controlling the fuel temperature between 10 and 80 °C. Horiba 7100 DEGR is an integrated gas analyzer that combines various emission detectors together by using the same sample point is used for gaseous emission measurement. A sample probe is installed ahead of the aftertreatment devices and the sample probe is thermally insulated to avoid condensation of particulates during measurement.

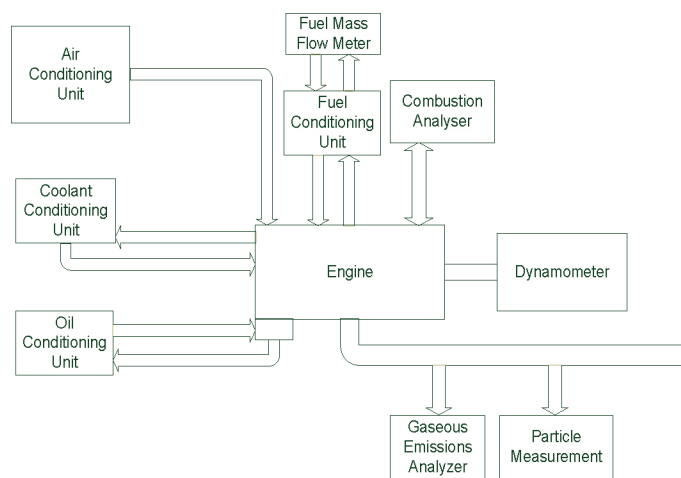


Figure 1. Schematic of the test facility

Table 1. Engine Specification

Engine Type	Gasoline Engine
Fuel system	Multi point fuel injection
Engine size	1196 cc
No. of cylinders x valves/cylinder	4 x 4
Compression ratio	9.9
Maximum torque	101 Nm @3000 RPM
Maximum power	54 kW @6000 RPM

Test Fuel

Gasoline (Bharat Stage IV) meeting the IS: 2796 specification is used as base fuel and ethanol meeting IS:15464 specification is used as blending component. 5%, 10% and 20% ethanol (by volume) blended in gasoline is denoted as E5, E10 and E20 respectively. The physiochemical properties of ethanol-gasoline blends is given in [Appendix-I](#).

Test Methodology

Engine tests were carried out at full throttle opening condition using E0, E5, E10 and E20 on the gasoline engine in the weather controlled test cell. The engine test bed control parameters for the test are given in [Table 3](#). Throttle position is maintained at 100% opening (WOT) and speed increased from 1000 to 6500 rpm at a regular interval of 500 rpm. The engine performance parameters such as fuel consumption, power and torque; combustion parameters such as IMEP, combustion peak pressure and burn duration; and emission parameters such as CO, CO₂, THC and NO_x were measured.

Table 3. Test conditions

Engine parameters	Value
Test cell temperature	25±1 °C
Fuel temperature	25±1 °C
Intake air temperature	25±1 °C
Coolant temperature	90±1 °C
Oil temperature	95±1 °C

RESULTS AND DISCUSSION

Engine Performance

Engine Power

Figure 2 shows the power curve for the engine running on ethanol-gasoline blends for the speed ranging from 1000 to 6500 RPM. It is seen that engine power for the different ethanol-gasoline blends are up to 2.5% higher than gasoline during full throttle opening tests.

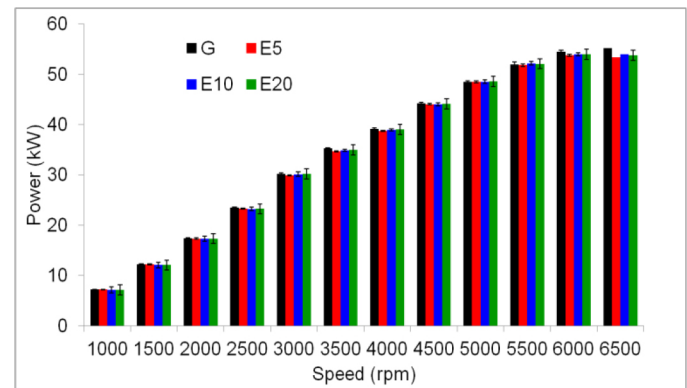


Fig 2. Engine Power for ethanol blended gasoline

Higher octane number of ethanol increases the octane quality of the blends. Moreover, higher heat of vaporization (i.e. higher volumetric efficiency) helps in cooling of air-fuel mixture and hence increase the density of the mixture. Further higher laminar flame speed of ethanol makes ethanol blends combust faster than gasoline and thus increased the power output marginally. The above positive effects neutralize the consequence of lower calorific value of ethanol [13, 14].

Engine Torque

The maximum torque observed for the engine at different speeds over the WOT test is depicted in [Figure 3](#). Engine torque output increased with the engine speed upto 3000 rpm and with further increase in speed reduction in torque was observed. At full throttle opening conditions, mass of air entering the engine almost remains same but the amount of fuel injected is varies to maintain the stoichiometric air-fuel ratio based on the feedback received from lambda sensor. When ethanol blended gasoline used, the ratio of air-fuel mixture became leaner and the ECU would reduce the fuel injection quantity to maintain the air fuel ratio. Ethanol blends has given relatively higher torque than gasoline for the all speed conditions. The torque of the engine running at 3000 rpm for the E5, E10 and E20 were 1.4%, 2.2% and 2.5% higher than gasoline. This performance improvement is due to higher octane number and oxygen content in the fuel blends which improved the combustion.