Jurnal
Teknologi

Full Paper

PERFORMANCE EVALUATION OF FOUR-STROKE SI (SPARK IGNITION) ENGINE USING ETHANOL-GASOLINE BLEND E50 AT VARIABLE LOAD AND COMPRESSION RATIO

Article history
Received
14 March 2016
Received in revised form
2 August 2016
Accepted
10 December 2016

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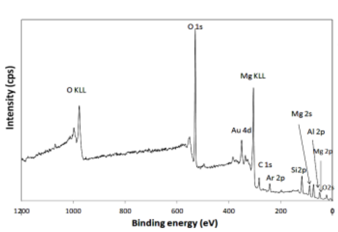
Graphical abstract



Abstract

Due to combination of factors, such as environmental concerns, high oil prices and the potential for peak oil, development of cleaner alternative fuels and advanced power systems for vehicles has become a high priority for many governments and vehicle manufacturers around the world. Use of Gasoline as an alternative fuel in Gasoline engine is becoming a need, looking at the scarcity of petroleum fuels in near future. This paper investigates the influence of compression ratio and ethanol-gasoline blending to find the effects on four-stroke SI engine performance. In this research, air cooled engine having compression ratio of 9.1 & 9.7 is used. Fuel blend E50 is used in the study and engine operated at a speed range of 600-1100 rpm. Maximum power was obtained for E50 fuel at a compression ratio of 9.1, while, a minimum fuel consumption rate was obtained at a compression ratio of 9.7. This clearly depicts that as compression ratio increases, fuel consumption rate decreases considerably. Further, experimental results showed that comparing several blends, 50% ethanol is cost and power effective for the four-stroke SI engine.

Keywords: Internal combustion engine, ethanol-gasoline blends, engine performance, alternative Fuel, ethanol as fuel

1.0 INTRODUCTION

Approximately 21x10^9 liter of ethanol, consumed per annum by the world for fuel purposes. This in turn makes ethanol a viable alternative to reduce the greenhouse effect [1], which also reduces dependence on oil imports and minimize the environmental threat caused by fossil fuels [2, 3]. Ethanol can be developed from diverse types of biomass, thus making it a renewable fuel which limits the release of fossil carbon dioxide (CO_2) and largely contributes its role in the global climatic changes [4, 5]. Moreover ethanol as a fuel is an octane enhancer and it reduce emissions from exhausts, i.e. carbon monoxide (CO) [4].

Literature reflects that with increasing gap between the energy requirement of the industrialized world and inability to replenish such needs from the limited sources of energy like fossil fuels, an ever increasing levels of greenhouse pollution from the combustion of fossil fuels in turn aggravate the perils of global warming and energy crisis. Motor vehicles account for a significant portion of urban air pollution in much of the developing world. According to literature, motor vehicles account for more than 70% of global carbon monoxide (CO) emissions and 19% of global carbon dioxide (CO2) emissions. CO2 emissions from a gallon of gasoline are about 8 kg.

Ethanol increasingly promoted as alternate transport fuel consequent in less greenhouse gas (GHG) emissions as compared to the gasoline, economical and consider antiknock fuel [1, 6, 7]. The significant environmental advantage of ethanol is that, unlike gasoline and diesel, its consumption does not significantly raise atmospheric intensity of "CO_2" [8]. This is because "CO_2" is counter-balanced by the environment through photosynthesis [9]. On a life cycle basis, ethanol produced today roughly reduces 20% GHG emissions, and in terms of fossil energy, it delivers one third or more energy [10, 11]. This GHG emission reduction could be increase by producing ethanol from more abundant cellulosic biomass sources [12]. E_{85} from feedstock to ethanol pathways evaluated 43%-57% less GHG emissions as compared to than a vehicle operated on conventional gasoline [10]. Ethanol-to-petroleum output/input ratios ranged from 10:1 to 13:1 but could be increased to 19:1, if farmers adopted high-yield progressive crop and soil management practices [9]. If ethanol has the potential to significantly reduce global GHG emissions associated with transportation, controls are definitely needed to protect ecologically important lands and the production efficiency and environmentally friendliness has to be incontestably improved as well [13].

Adapting the ethanol fuel to the engine it is necessary to enhance the compression ratio or modified fuel Injection system, such that it is adequate for all operating conditions. For smooth operation of an engine, combustion must spread smoothly throughout the combustion chamber [14]. This was accomplished in high compression spark Ignition with high pressure manifold Injection having a homogeneous mixture in the cylinder ignited by means of a spark. Discharge of "NO_x" through exhaust decreased by approximately 50% as the ethanol blending increase from "E_0 to E_{30}-E_{40}", while no further decrease reported by increasing blending ratio with "E_{55}" [15]. Pollutants from engines are nitrogen oxides "NO_x", smoke and particulate matter[8]. By adding ethanol to the fuel "CO" and "HC" emissions concentrations in the engine exhaust decrease dramatically [16-19]. Moreover, the specific fuel consumption, "CO", "CO_2", "HC" and "NO_x" emissions were reduced by about 3%, 53%, 10%, 12% and 19%, respectively [20].

Ethanol is an attractive alternative fuel because it is a renewable bio-based resource and it is oxygenated, thereby providing the potential to reduce particulate emissions in spark–ignition engines. In previous investigations the properties and specifications of ethanol blended were studied at lower blending ratio (E10, E20, E30) or either at very high blending ratios (E85, E100) with gasoline fuel are examined. In this research special emphasis is placed on the factors critical to the potential commercial use of the blend (E50). These factors include blend properties, engine performance i.e. thermal efficiency, power, brake specific fuel consumption and cost analysis etc.

In this paper four-stroke engine performance and effect of enhance compression ratio was studied. Study was carried out by adopting ethanol, gasoline, and ethanol blends as fuel. The outcomes of ethanol blends and mechanical variations of the air/fuel ratio on the output power explored, both for gasoline and ethanol blends. At existing, four-stroke engines, blends i.e. 10-50% ethanol by volume are of main concern, however for prospect demands, it is important to explore the effects of higher ethanol blends and pure ethanol. However, for higher blends, modifications in prevailing engine were critical, optimization of fuel ignition system and improvement in compression ratio might be vital for smooth working. The engine used in this study was optimized to operate on ethanol fuel blends, so the study shows the effects that can be expected for engines already in-use and with improvement in compression ratio.

Table 1 Chemical and Physical Properties of Fuels

PROPERTY	METHOD	ETHANOL	GASOLINE
Formula		C_2H_5OH	C_4-C_{12}
Molecular Weight		46.07	100–105
Specific heat (kJ/kg K)		2.4	2.0
Viscosity (mPa s) at 20 °C		1.19	0.37–0.44
Lower heating value (MJ/m³)		21.1	30–33
Flash point (°C)		13	−43
Auto-ignition temperature (°C)		423	257
Specific heat (kJ/kg K)		2.4	2.0
Viscosity (mPa) at 20 °C		1.19	0.37–0.44
Research Octane number (RON)	ASTM D 2699	120-135	95.5
Motor Octane number (MON)	ASTM D 2700	100-106	85
density (15 °C), g/mL	ASTM D 4052	0.79	0.739
lower heating value, MJ/kg	SS 155138	26.7	43.8

Values are given for pure fuels, without addition of oil "All properties content from Automotive Fuels Reference Book"[21, 22]

2.0 METHODOLOGY

2.1 Engine

This study is carried out on Chinese engine with a displacement of 78cm³ and maximum power 5.3 KW at 6500 rpm. In this study gasoline engine has compression ratio of 9.1:1 and due to the high octane rating of ethanol blend E_{50}, enhanced compression ratio required for better efficiency. Knocking, however, is a limitation for increasing the compression ratio [23]. Number of methods were adopted by the researchers to increase the compression ratio of an engine. In this study engine modified by milling process to achieve compression ratio 9.7.

2.2 Fuel

A total of five fuels were employed in the study. The fuel test matrix included gasoline which served as the baseline fuels for the study of the ethanol blend namely, E_{25} (75% regular gasoline blend with 25% Ethanol), E_{50} (50% regular gasoline blend with 50% Ethanol), E_{75} (25% regular gasoline blend with 75% Ethanol) and E_{100} (pure Ethanol) after extensive experimentation only one ethanol-gasoline blend E_{50} was selected for detail experimentation and comparative studies. The Details properties of both fuels chemical and physical are given in Table 1.

2.3 Test Equipment

The Chinese engine is tested on a test bench, equipped with dynamotor. Engine test bed equipped with comprehensive instrumentation to investigate the operating characteristics i.e. power, rpm and torque measurement etc. The equipment is fully compatible assists accurate real-time data capture, monitoring and display, calculation and charting of all relevant parameters on a computer (PC available separately) making tests quick and reliable.

2.4 Test Procedure

A steady state mode procedure based on fuel blends analysis was used as basis for the measurements of critical performance parameters. Running the engine on variable load, full load and no load (idle) conditions.

In this study, the engine is tested at variable load excluding idle mode. Change in compression ratio significantly affect engine performance the experimentation was done at two different compression ratios. Testing comprises on two phases initial phase engine is tested on Compression ratio 9.1:1 while The Second phase were performed by achieving compression ratio up to 9.7:1.

As change in air/fuel ratio also significantly disturbed engine performance and emissions as well [24-27]. The experimentation done at multiple air/fuel ratios for gasoline and ethanol blend to cover the maximum range of operations for each fuel. Initially air/fuel ratio was tested by adjusting carburetor, set as lean as possible. These limitation were chosen in order to avoid breakdown of engine. The other air/fuel ratio were chosen set accordingly to prevent engine from misfiring. All settings were run consecutively, without switching off the engine.

2.5 Technical Parameters

The brake load measured through dynamometer by the standard procedure for each sample[28]. Fuel consumption was measured by measuring time consume to intake specific volume of fuel sample. Measure air/fuel ratio take mass flow rate of air from engine analyzer and fuel mass flow rate can be calculated form volume flow rate of fuel and their ratio will gives us A/F ratio of the fuel. Power output, engine speed and torque were recorded continuously during the experiment of sampling using a multichannel data logger.

3.0 RESULTS AND DISCUSSION

The following discussion is primarily focused on comparative study of ethanol-gasoline blend (E_{50}) with gasoline, by modifying compression ratio. Results obtained from this experimental study have shown in the form of graphs. Results obtained for break specific fuel consumption, break power and thermal efficiency.

3.1 Relation between Power and RPM

Literature [29] suggests that there is a direct relation between Power and RPM and same trend was found after experimentation. Before making changes in the engine (CR 9.1), there is a considerable difference between Power generated by gasoline and E_{50} at higher RPM as shown in Figure 1 but this variance become negligible after increasing the compression ratio (9.1 to 9.7) as shown in Table 2 shows the maximum Power and RPM of gasoline and E_{50} for original and modified CR.

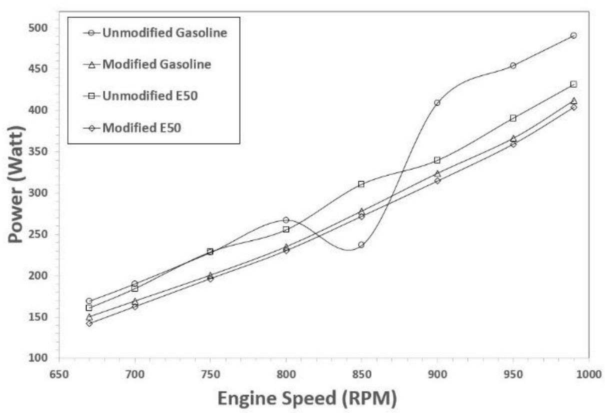


Figure 1 Break Power for modified and non-modified engine for different fuels, operating at different engine speeds

Table 2 Comparison of air/fuel ratio for different fuels

Sr. No	RPM	Gasoline **U.M A/F	Gasoline *M A/F	E_{50} **U.M A/F	E_{50} *M A/F
1	690	14.08	11.89	9.45	4.31
2	700	13.65	11.63	9.15	4.28
3	725	12.62	10.97	8.41	4.22
4	750	11.66	10.32	7.66	4.15
5	775	10.70	9.27	7.15	3.96
6	800	9.73	7.83	6.99	3.71
7	810	9.35	7.26	6.87	3.61

At Maximum RPM A/F Ratio

Fuel	RPM	A/F Ratio
Gasoline U.M	994.22	8.81
Gasoline M	1084	5.98
E_{50} U.M	1055	5.15
E_{50} M	1090	3.58

*M=Modified, **U.M=Un.Modified

3.2 Relation between Air Fuel Ratio and RPM

The RPM increase the Air Fuel Ratio decreases [29] and the same pattern observed in experimentations. The A/F ratio for Gasoline is higher than E_{50}. In the starting phase of engine, need more fuel than air to start the engine and to overcome the frictional effects, but right after starting phase A/F ratio become high, as amount of air present for mixing is more than amount of fuel. Less fuel is required to run the engine but increasing rpm need's more fuel to burn while amount of air present for mixing is almost same which ultimately decreases the A/F ratio.

The Air Fuel ratio of gasoline and E_{50} for original and modified CR at same RPM is shown in Table 2 the air fuel ratio of gasoline and E_{50} for original and modified CR at their respective maximum RPM are shown in Table 2.

3.3 Relation between Brake Specific Fuel Consumption and RPM

Brake specific fuel consumption (BSFC) is a measure of the fuel efficiency of a shaft reciprocating engine. It is the rate of fuel consumption divided by the power produced. It is important for to know, how much fuel is consumed to produce a specific amount of power and BSFC tells us the same thing. Shown in the Figure 2.

$$bsfc = \frac{\dot{m}}{Power} = \frac{kg}{KWh} \tag{1}$$

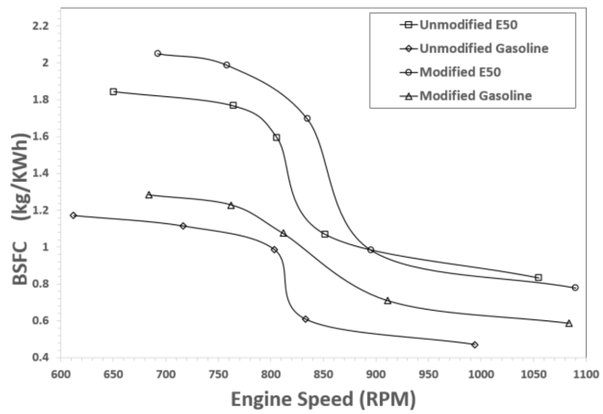


Figure 2 Break specific fuel consumption for modified and non-modified engine for different fuels, operating at different engine speeds

3.3 Relation between Thermal Efficiency and RPM

$$\eta_{th} = \frac{Power}{(\dot{m})(Cv)} \tag{2}$$

The thermal efficiency increases with the increase in RPM [29] and same trend is found after experimentations. Variations of efficiency against different RPM before and after engine modifications. It is clearly reflected in graph that the efficiency of gasoline is higher than E_{50}. But performance of gasoline decreases after modification, because of the fact that disturbance in optimal design. However, E_{50} performs well after modification. This can be easily seen from the Figure 3.

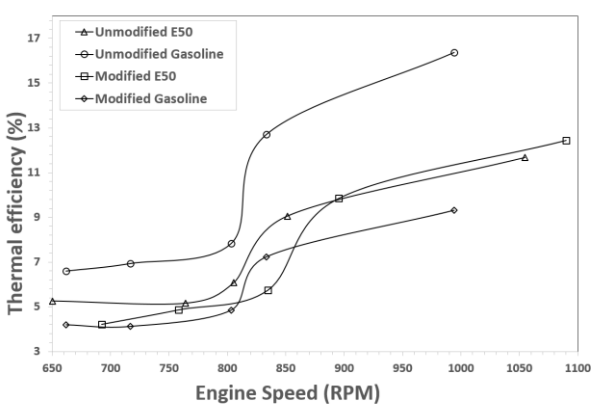


Figure 3 Thermal efficiency for modified and non-modified engine for different fuels, operating at different engine speeds

3.5 Cost Comparison of Gasoline and E_{50}

Finally the cost comparisons were very important to check the feasibility of the project. Cost analysis was done on the basis of cost per liter of fuel (Gasoline PKR 104/liter and E_{50} Pakistan Rupees, PKR 73/liter). The cost comparison is done at higher RPM i.e. 990 rpm the comparison results shown in Figure 4.

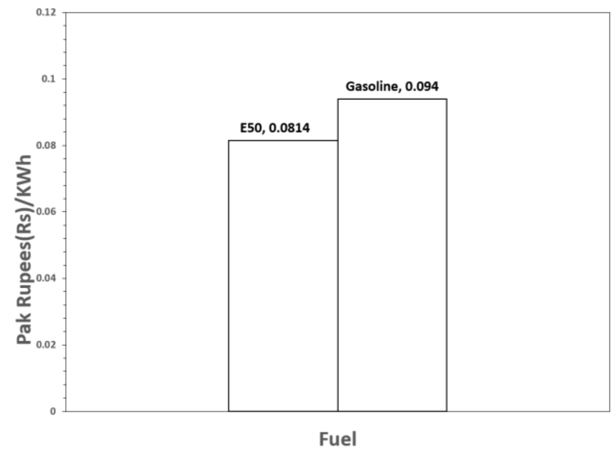


Figure 4 Cost comparison for gasoline and E50

4.0 CONCLUSION

In the current energy scenario in the world, ethanol is the one of the best alternative to overcome the energy crisis. To reduce the dependence on fossil fuels not only reduces the energy crisis, but also help to control environmental pollution. The temperature is changing and everything that happens, because our dependence on fossil fuels such as gas (GHG) emissions. "CO" Gas and "CO_2" emissions are much higher than the permissible limit. Greenhouse gas emissions from ethanol are about 19% to 86 % less than gasoline. In addition, the costs of ethanol lower. So ethanol is a viable solution.

The results of the experiments are very worthy. So it means, minor changes in engine gives significant improvements in compression ratio, results as indicated

(i). Significant increase in power with E_{50}.
(ii). Reduces the power difference between gasoline and E_{50} with the same RPM.
(iii). Fuel consumption has decreased E_{50}.
(iv). Increase the efficiency of E_{50}.
(v). The decrease cost per kilowatt - hour at the same speed E_{50} than gasoline.

Acknowledgement

The authors are very thankful to HITEC University, Taxila, Pakistan for providing samples and necessary testing facilities.

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