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Performance and Emission Characteristics of SI Engine Using LPG and Ethanol Fuels: A Review

Dr B D Nandre[1], Dr. Atul Patil[2], Dr. Sarika Atul Patil[3]

[1] Department of Mechanical Engineering, M.E. S. College of Engineering,Pune, Savitribai Phule Pune University,Pune,India

[2]Professor, Dr. D. Y. Patil Institute of Technology,Pimpri, Pune

[3]Asst. Professor, Dr. D. Y. Patil Institute of Technology, Pimpri, Pune,

[1]bhushan.nandre@gmail.com [2] patilatul20@gmail.com [3]sapsarikapatil@gmail.com

Abstract-The fuel limitation and environmental pollutions are important for human kind to find alternative fuels and sustainable energy. Fossil fuel is major used to provide energy for transportation and industrial sectors. However, demanding of fuel is rising and unlimited which completely opposites with production ability and limited crude oil. Accordingly, an increasing of fuel price is continuing crisis and impact. Many automobiles were modified to be used with various alternative fuels as other choices instead of gasoline and diesel. Alternative fuel such as natural gas, hydrogen, biomass, vegetable oil and alcohol fuel are sought as an option for automobile. LPG and Ethanol are attractive fuel choices for many commercial vehicles and industries because of cheap cost, reasonable octane number, and also low emissions than conventional gasoline. Air-fuel ratio, operating cylinder pressure ignition timing and compression ratio are some of the parameters that need to be analyzed and optimally exploited for better engine performance and reduced emissions. In the present paper a comprehensive review of various operating parameters and concerns have been prepared for better understanding of operating conditions and constrains for a LPG and Ethanol fuelled internal combustion engine.

Keywords - LPG, Ethanol, Spark ignition engines, Dual fuel engine, Combustion characteristics, performance characteristics and Emissions.

1. INTRODUCTION

The increasing demand for energy and stringent pollution regulations, as a result of the population growth and technological development in the world, promote research on alternative fuels. In this sense, using alternative fuels such as alcohol fuels and gaseous fuels in internal combustion engines have the potential to reduce the dependency on petroleum fuels and exhaust emissions. Ethanol for example, has been identified as having the potential to improve air quality when used to replace conventional gasoline in engines because of its good anti-knock characteristics and the reduction of CO and unburned hydrocarbon (HC) emissions. Presently, ethanol is used in spark-ignition engines with gasoline at low concentrations without any modification. Pure ethanol can be used in spark-ignition engines but necessitates some modifications to the engine [1]. Ethanol (C_2H_5OH) is a high performance, biomass fuel. It is considered the most suited alcohol to be used as a fuel for spark ignition engines. The most attractive properties of ethanol include its ability to be produced from renewable energy sources, its high octane number, and its high laminar flame speed. Drawbacks include its relatively low heating value and the fact that it is corrosive to metal and rubber parts of the engine. Recently, ethanol has received attention as a potential transportation fuel of the future. The present cost of ethanol is high due to the manufacturing and processing required. Some studies show that the production and distribution of ethanol, actually consumes more energy than what is present in the final product. This would defeat a major reason of using an alternate fuel. Also, high production of ethanol would create a food-fuel competition, resulting in higher costs for both. Thus, the use of 100% ethanol in internal combustion engines on a wide scale is not plausible at the present time. However, ethanol blends with gasoline are commonly used in the United States [15].

Liquefied petroleum gases (LPGs) are by-products of natural gas productions and refineries, and they are widely used in commercial vehicles. LPGs mainly consist of mixtures of hydrocarbons such as propane (C_3H_8), propene (C_3H_6), *n*-butane (C_4H_{10}), isobutene (methyl-propane), and various proportions of other butanes (C_4H_8). Traces of ethane may also exist in the mixture. LPG and other gaseous fuels share common properties that make them attractive relative to gasoline. The LPG energy content (High Heating Value, HHV) is 46.23 MJ/kg. The high octane rating and the low carbon and oil contamination characteristics of LPG result in a documented longer engine lifetime, up to twice that of the gasoline engines. Because the fuel mixture is fully gaseous, cold start problems associated with liquid fuel are eliminated. LPG has a relatively high energy content per unit of mass, but its energy content per unit volume is low. Thus, LPG tanks have more space and weight than petrol or diesel fuel tanks, but the range of LPG vehicles is equivalent to that of petrol

Vehicles [13].

1.1 Ethanol and LPG as an alternative fuel for IC engine

Worldwide ethanol production for transport fuel raised between the years 2000 to 2007 from 17 billion to more than 52 billion litres. From 2007 to 2008, the share of ethanol in global gasoline type fuel use increased from 3.7% to 5.4%. In 2009, worldwide ethanol fuel production reached 19.5 billion gallons (73.9 billion litres).It is forecasted that the global use of ethanol will increase 25 times by 2020 [3].

This paper addresses the performance and environmental concerns of using neat ethanol and liquified petroleum gas (LPG) as transportation fuels.LPG, which consists mostly of propane, is already used extensively as a vehicle fuel in the United States, but its use has been limited primarily to converted fleet vehicles. Increasing U.S. interest in alternative fuels has raised the possibility of introducing neat-ethanol vehicles into the market and expanding the number of LPG vehicles. Use of such vehicles, and increased production and consumption of fuel ethanol and LPG, will undoubtedly have environmental impacts. If the impacts are determined to be severe, they could act as barriers to the introduction of neat-ethanol and LPG vehicles. Environmental concerns include exhaust and evaporative emissions and their impact on ozone formation and global warming, toxic emissions from fuel combustion and evaporation, and agricultural impacts from production of ethanol [2]. The performance and emission characteristics of SI engine using LPG and Ethanol as a fuel and related concerns are reviewed in this paper. Comparative properties of LPG, Ethanol and gasoline are as follows.

Table 1: Comparative properties of LPG, Ethanol and Gasoline [10]

Properties	**LPG (70%C4H10+30%C3 H8)**		**Ethanol**	**Gasoline**
	C_4H_{10}	C_3H_8	C_2H_5OH	
Density (Kg/m^3)	2.52	1.91	789	700
Molecular mass (kg/kmole)	58.12	44.09	46.06	100.2
Boiling point(^{o}c)	-1	-42	78.37	38-204
Autoignition temperature(^{o}c)	405	470	365	280
Calorific value (KJ/Kg)	49510	50350	29700	47300
Stoichiometric fuel-air ratio	0.0646	0.0638	0.1112	0.0659
Research Octane number	94-96	107	108.6	96-98

2.PERFORMANCE AND EMISSION CHARACTERISTICS OF ETHANOL FUELED SI ENGINE

Fikret Yuksel, Bedri Yuksel [4] investigated experimentally, the availability analysis of a spark-ignition engine using ethanol–gasoline blend. Sixty percent ethanol and 40% gasoline blend was exploited to test the performance, the fuel consumption, and the exhaust emissions. As a result of this study, it is seen that a new dual fuel system could be serviceable by making simple modifications on the carburettor and these modifications would not cause complications in the carburettor system. Experimental results indicated that using ethanol–gasoline blended fuel, the torque output consumption of the engine increased slightly, the CO and HC emissions decreased dramatically as a result of the leaning effect caused by the ethanol addition, and the CO_2 emission increased because of the improved combustion. In this study, it was found that using ethanol–gasoline blended fuel, the CO and HC emissions would be reduced approximately by 80% and 50%, respectively, while the CO_2 emission increases 20% depending on the engine conditions.

M.A.Ceviz , F.Yuksel [5] investigated the effects of using ethanol–unleaded gasoline blends on cyclic variability and emissions in a spark-ignited engine. One important design goal for spark-ignited engines is to minimize cyclic variability. A small amount of cyclic variability (slow burns) can produce undesirable engine vibrations. On the other hand, a larger amount of cyclic variability (incomplete burns) leads to an increase in hydrocarbon consumption and emissions. Results of this study showed that using ethanol–unleaded gasoline blends as a fuel decreased the coefficient of variation in indicated mean effective pressure, and CO and HC emission concentrations, while increased CO_2 concentration up to 10vol% ethanol in fuel blend. On the other hand, after this level of blend a reverse effect was observed on the parameters aforementioned. The 10vol% ethanol in fuel blend gave the best results.

Hakan Bayraktar [6] investigated experimentally and theoretically the effects of ethanol addition to gasoline on an SI engine performance and exhaust emissions. In the theoretical study, a quasi-dimensional SI engine cycle model, which was firstly developed for gasoline-fueled SI engines by author, has been adapted for SI engines running on gasoline–ethanol blends. Experimental applications have been carried out with the blends containing 1.5, 3, 4.5, 6, 7.5, 9, 10.5 and 12 vol% ethanol. Numerical applications have been performed up to 21 vol% ethanol. Engine was operated with each blend at 1500 rpm for compression ratios of 7.75 and 8.25 and at full throttle setting. Experimental results have shown that among the various blends, the blend of 7.5% ethanol was the most suitable one from the engine performance and CO emissions points of view. However, theoretical comparisons have shown that the blend containing 16.5% ethanol was the most suited blend for SI engines. Furthermore, it was demonstrated that the proposed SI engine cycle model has an ability of computing SI engine cycles when using ethanol and ethanol–gasoline blends and it can be used for further extensive parametric studies.

Ibrahim Thamer Nazzal [7] investigated the effects of alcohol blends on the performance of a typical spark ignition engine and compare the engine performance with using 12%ethanol–88%gasoline blended fuel and 12%methanol–88%gasoline blended fuel and 6 ethanol -6 methanol – 88 gasoline with gasoline fuel .The engine performance was measured at a variety of engine operating conditions .The results are presented in terms of speed and their effects are indicated that when ethanol–gasoline and methanol–gasoline blended fuel is used, the brake power of the engine slightly increase. While the brake thermal efficiency showed increase compared with gasoline fuel .At the same time, it can be found that b.s.f.c also enhance compared with gasoline fuel. The exhaust gas temperature decrease compared with gasoline fuel.

3.PERFORMANCE AND EMISSION CHARACTERISTICS OF LPG FULLED SI ENGINE

K F Mustafa, H W Gitano-Briggs [9] carried out an experimental investigation of a Liquefied Petroleum Gas (LPG) fueled four-stroke spark ignition engine. The primary objective of the study was to determine and quantify the exhaust emissions from the engine. The engine used in the study was originally a four-stroke spark ignition gasoline engine and minor modifications were carried out to permit the experiments to run on LPG fuel. This includes the incorporation of an adaptor which functions as a mixer in the intake manifold of the engine. The volume percentage of LPG fuel in gasoline used in the experiments was varied at 5%, 10% and 20%, and the amount of LPG fuel injected is controlled by the PLC controller. Bubbling method was employed during calibration to approximate the amount of LPG required with the amount calculated from theory. During the running, the engine was coupled to a 5kW eddy current dynamometer to measure several engine performance parameters and a 5-gas analyzer with non dispersive infra-red (IR) was inserted into the engine exhaust tailpipe for measuring the exhaust emissions. The engine speed was maintained at an idling condition of 4000rev/min throughout the experiment. It was found that the level of carbon dioxide (CO_2) peaked at around relative air-fuel ratio of 1.0 and carbon monoxide (CO) exhibits a sharp decreased as the relative air-fuel ratio increases. Unburned hydrocarbons (UHC) also shows marked reduction as the relative air-fuel ratio exceeds stoichiometric and nitrogen oxides (NOx) exhibits an increasing trend as the relative air-fuel ratio increases.

Kansuwan P., and Kwankaomeng S.[10] investigated The engine performance and exhaust emissions of a small engine. The engine with displacement of 197 cm^3 was minor modified and operated with gasoline, liquefied petroleum gas (LPG) and ethanol fuel mixture blending 20% ethanol and 80% gasoline (E20). The engine testing was done over a wide range of engine speed. Engine power, fuel consumption and exhaust emissions of the engine using gasoline, LPG, and E20 were measured and compared. The experimental results showed that small engine operated with LPG had lowest power and torque while engine operated with gasoline and E20 had comparable power. However, using LPG on small engine had lowest fuel consumption and carbon monoxide (CO) emission compared to that of using gasoline and E20. Engine operated with E20 provided least hydrocarbon (HC) concentration than that of LPG and gasoline. Considering the results of engine power and exhaust emissions, using gasoline on small engine gave the best output engine power while using LPG and E20 had lowest CO emission and lowest HC concentration, respectively.

Thirumal mamidi, Dr.J.G.Suryawnshi. [11] Carried out investigations on S.I. engine using Liquified Petroleum Gas (LPG) as an alternative fuel. Experimental investigations have been carried out to performance and emissions of single cylinder four-stroke spark ignition engine at full throttling position of engine and different load conditions is used to different fuels (Gasoline and LPG). The results showed that CO and HC emissions increase as the compression ratio, speed, and load increase. In the case of using LPG in SI engines, the burning rate of fuel is increased, and thus, the combustion duration is decreased. Therefore, the cylinder pressures and temperatures predicted for LPG are higher compared to gasoline. LPG is free of lead and has very low sulphur content. When using Gasoline fuel the BSEC consumption values slightly lower than the using LPG fuel. Because the C.V. of Gasoline is (43MJ/Kg) less compared to the LPG (46.1MJ/Kg).When load increase on the engine the CO,HC and CO_2 emissions also increase. However, these emissions higher for Gasoline when compared with LPG.

Vezir Ayhan, Adnan Parlak [12] Showed the effects of LPG injection during air inlet period on emissions and performance characteristics. They had modified the engine to determine the best LPG composition for dual operation in order to improve the emissions quality while maintaining high thermal efficiency in comparison to a conventional diesel engine was done. An electronic controlled LPG injection system has been developed for this purpose. LPG injection rate were selected as 5, 10, 15 and 25% on a mass base. Minimum SFC and maximum brake efficiency obtained with 15% LPG between 1400 and 1800 rpm engine speeds. Optimum injection rates is found at 5% LPG in terms of exhausts emissions and performance. At this injection rate, SFC, NOx and smoke emissions decreased by 9, 27.6 and 20% at the test speed of 1600 rpm, respectively.

CONCLUSION

Based on the reviewed paper for the emissions and performance, its concluded that the Ethanol and LPG represents good alternative fuels for gasoline and therefore must be taken into consideration in the future for transport purpose. Using LPG as a fuel gives significant reduction in CO, CO_2 emissions, and NO_X emissions are higher because of higher flame temperature in the combustion chamber. While formation of NOX could be potentially lower with ethanol as combustion temperature is lower. Gasoline-ethanol blend fuelled and LPG-fueled vehicles using current aftermarket conversion technologies have shown better emission performance as compared with gasoline vehicles.

NOMENCLTURE

ABBREVIATIONS AND MEANINGS

LPG- Liquified Petroleum Gas

BSFC- Break Specific Fuel Consumption

BSEC- Break Specific Energy Consumption

UHC- Unburned hydrocarbons

ESTAP-Energy Technology Systems Analysis Programme

HHV-Higher Heating Value

CO- Carbon Monoxide

CO_2- Carbon dioxide

HC- Hydrocarbon

NO_X- Nitrogen oxide

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