JJMIE

Volume 5, Number1, February 2011
ISSN 1995-6665
Pages 47 - 52

Jordan Journal of Mechanical and Industrial Engineering

Comparative Performance and Emission Properties of Spark-Ignition Outboard Engine Powered by Gasoline and LPG

Zuhdi Salhab*, Mohammad G. Qawasmi, Hussein Amro, Mosa Zalloum, Mohammad S. Qawasmi and Nafez Sharawi

Department of Mechanical Engineering, Palestine Polytechnic University,Hebron, Palestine

Abstract

This paper presents an experimental research into the use of LPG in converting spark-ignition four stroke outboard (experimental) engine. Engine was modified to operate either on gasoline or on alternative fuel. Two different methods were adapted for operation with LPG; the first method is using vacuum produced by engine which supplies a constant mixture to the engine carburetion while the second one is accomplished using fuel injection (LPG). The results obtained indicate that with the use of injected LPG; torque, engine brake power and brake specific fuel consumption were lower compared to gasoline, while for vacuum system are higher except brake power. On the other hand, the carbon monoxide (CO), carbon dioxide (CO_2) and nitrogen oxides (NO_x) emissions were less in LPG mode as compared to gasoline mode while the higher hydrocarbons (HC) emissions were obtained.

Keywords: Gasoline, LPG, Performance, Emissions, Engine.

1. Introduction

Over the past decade, alternative fuel had been studied for the possibility of lower emission, lowerfuel cost, better (more secure) fuel availability and lower dependence on petroleum. The major alternative fuels under consideration are LPG, methanol, ethanol, natural gas and hydrogen.LPG is obtained from hydrocarbons produced during refining of crude oil and from heavier components of natural gas. It is petroleum derived colorless gas LPG consists of propane or butane or mixtures of both. Small quantities of ethane or pentane may also be present. LPG has high octane rating of 112 RON which enables higher compression ratio to be employed & hence gives higher thermal efficiency. Due to low maintenance cost, economic market price and environment friendly characteristics LPG is becoming popular alternative for gasoline. LPG has the following characteristics against gasoline:

• Relative fuel consumption of LPG is about ninety percent of that of gasoline by volume.
• LPG has higher octane number of about 112, which enables higher compression ratio to be employed and gives more thermal efficiency.
• Due to gaseous nature of LPG fuel distribution between cylinders is improved and smoother acceleration and idling performance is achieved. Fuel consumption is also better.

• As LPG is stored under pressure, LPG tank is heavier and requires more space than gasoline tank.
• Engine life is increased for LPG engine as cylinder bore wear is reduced & combustion chamber and spark plug deposits are reduced.
• There is reduction in power output for LPG operation than gasoline operation.
• Starting load on the battery for an LPG engine is higher than gasoline engine due to higher ignition system energy required.
• LPG system requires more safety. In case of leakage LPG has tendency to accumulate near ground as it is heavier than air. This is hazardous as it may catch fire.
• Volume of LPG required is more by 15 to 20% as compared to gasoline.
• LPG operation increases durability of engine and life of exhaust system is increased.
• LPG has lower carbon content than gasoline or diesel and produces less CO_2 which plays a major role in global warming during combustion.
• LPG powered vehicles have lower ozone forming potential and air toxic concentrations [1]-[4].

2. Engine Modification Systems for LPG Operation

Figures 1 and 2 show engine modified systems for LPG op

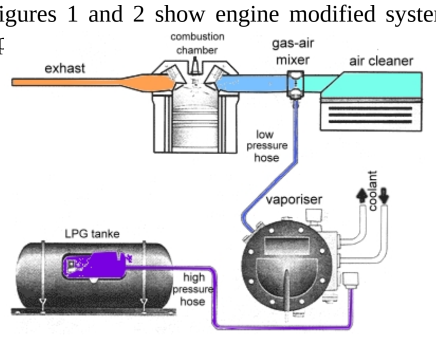

Figure1. Vacuum (mixing) system

*Corresponding author: zuhdisalhab@ppu.edu

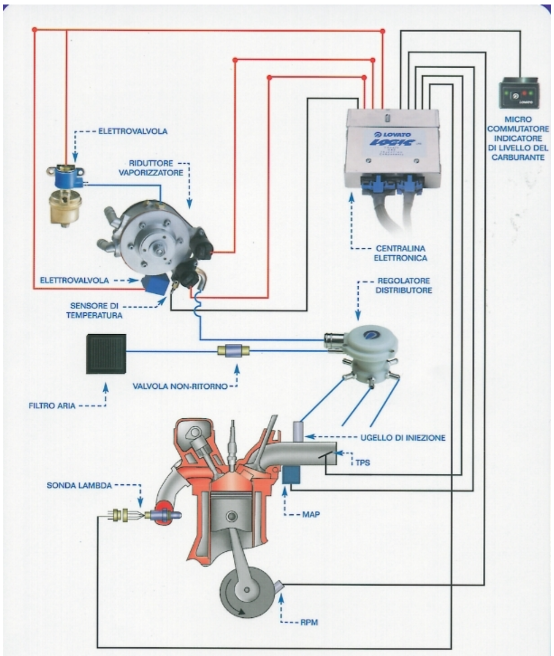

Figure 2. LPG injection system

First method uses vacuum produced by engine. The system supplies a constant air-fuel mixture to the engine (through gas-air mixer) while in the second system the fuel is injected at right time with right quantity according to engine operating conditions.

Usually a mixer (figure 1) is installed to the airflow just before the intake control valve, and it is essentially a tube which the air flows through. It has a carefully designed internal profile though, such that the air initially flows through a medium diameter hole, which then expands to the maximum internal diameter of the tube as the airflow continues. Since air has momentum, this creates a partial vacuum at the expansion point. This vacuum is proportional to the airflow rate and the LPG systems are used to meter the amount of gas joining the airflow. Just at this expansion point, there are some small holes inside the mixer. These pick up the partial vacuum and send this back along a pipe to a vaporizer. The vaporizer has a large diaphragm which responds to the amount of vacuum in the mixer. As this vacuum (i.e. airflow rate) increases, the diaphragm is pulled on (since the other side of it is referenced to normal atmospheric pressure) and this opens a progressive valve, which controls how much LPG is allowed in. So more LPG is expanded to gas. This gas goes back down to the same tube into the mixer, joins the airflow and goes off into the engine to be burnt in the same way as petrol. Open loop LPG system operates in the way described. A restrictor valve is added to the pipe between the mixer and the vaporizer, which the installer will use to tune the system. By adjusting this valve, the installer can tune how much of the vacuum the vaporizer experiences, so can control how much gas can join the airflow and so keep the engine in tune. However, vaporizer diaphragms bed in over time, so gradually the tuning drifts out. Also the response of the diaphragm to the vacuum is fairly course, and it's not always feasible to tune the system such that the correct mixture is presented to the engine under all loads and conditions. These systems do work, but they don't always provide the best performance and economy and need relatively regular re-tuning [5].

In the case of LPG injection system, this system was used on LPG mode by using fuel selector switch. If level in tank drops to certain point, gasoline system is automatically switched on. LPG cylinder supplies liquid LPG to LPG vaporizer which has heating element. Liquid LPG is vaporized and fuel in vapor form is supplied to gas mixer where air is mixed with fuel and supplied to engine manifold. Due to reduction in pressure there may be possibility of freezing within the vaporizer. To overcome this heated coolant is circulated through vaporizer. Fuel metering valve with step motor is used to vary quantity of fuel according to engine speed and load. Fuel shut off valve is used to cutoff fuel supply. Function of step motor and fuel shut off valve are controlled by electronic control unit (ECU). Intake manifold has manifold absolute pressure (MAP) sensor which measures manifold pressure and sends signal to ECU. Oxygen sensor is located in exhaust which measures oxygen in exhaust and sends signals accordingly to ECU. ECU receives these signals and calculates how much fuel is to be supplied and sends signal to fuel metering valve. RPM sensor measures speed and sends signal to ECU. ECU decides amount of fuel to be supplied depending of engine speed and sends signals to fuel metering valve [6].

3. Experimental Equipments

Engine was prepared for operation with gasoline and LPG. The experiments have been performed at the laboratory (automotive workshop) of the Mechanical Engineering Department at Palestine Polytechnic University which interests for a long time in alternative fuels and renewable energy. Experimental engine was connected to the THEPRA EPTS brake hydraulic dynamometer. The rotating torque of the engine is converted to a stationary torque that was measured. The turbulent action of the water absorbs the power of the engine. The load is controlled by the water inlet. The power is converted into heat which is carried away by the continually flowing water. EPTS with vertical Instrument Panel measures engine torque and power continuously from an absorption brake and produces value of torque and power for various RPM bands. Torque and power values are integrated during each shaft revolutions as the engine is slowly accelerated through a range of interest. Fuel consumption was measured while brake specific fuel consumption was determined.

Engine emissions (CO, CO_2, HC and NO_x) were measured on IM-2400- 4/5 gas analyzer at 1500 RPM and different loads. In this presented study, tested engine has characteristics shown in the following table:

Table1. Characteristics of the tested engine

Data	Unit	Gasoline	LPG
Engine type	-	4 stroke outboard	4 stroke outboard
Model	-	Mazda 323i	Mazda 323i
Chemical formula	-	C_8H_{18}	60% C_3H_8- 40% C_4H_{10}
Lower heating value	MJ/kg fuel	43	46.6
Start of ignition	CA^0	350	350
Ignition duration	CA^0	60	60
Number of cylinders	-	4	4
Bore/ stroke	mm	77.5/ 78	77.5/ 78
Connecting rode length	mm	133	133
Stoichiometric air/fuel ratio	-	14.7	15.6
Excess-air ratio	-	1	1
Compression ratio	-	10	10
Maximum power	kW	65	65

4. Experimental Results

Tests were conducted by varying torque and engine speed and measuring engine performance and emissions. The tests were repeated for gasoline and LPG as well. No modification of excess- ratio (air- fuel ratio) was made.

4.1. Engine Performance

Following graphs (figures 3-6) are plotted from tests results for gasoline and LPG (mixing and injection) which indicate the relation between brake specific fuel consumption (bsfc) in (g/kWh) with variation of engine speed at different values of torque measured at dynamometer and the relation between engine brake power (depending on torque) versus engine speed.

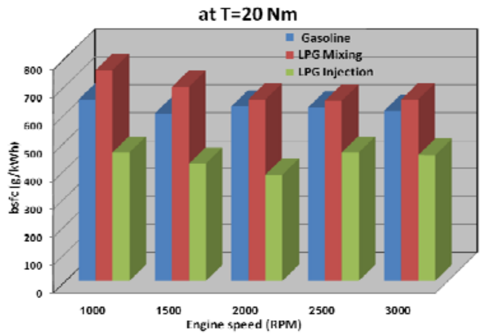

Figure 3. Brake specific fuel consumption (bsfc) versus engine speed at T=20 Nm

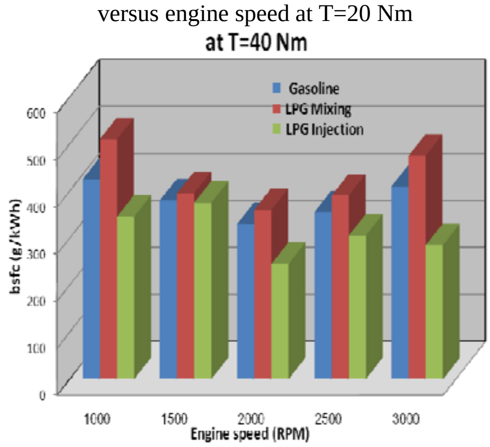

Figure 4. Brake specific fuel consumption (bsfc) versus engine speed at T=40 Nm

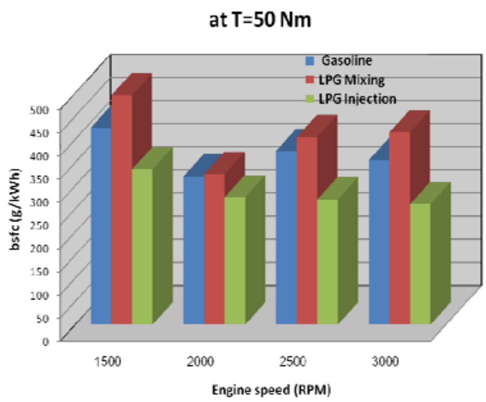

Figure 5. Brake specific fuel consumption (bsfc) versus engine speed at T=50 Nm

  – Volume 5, Number 1 (ISSN 1995-6665)

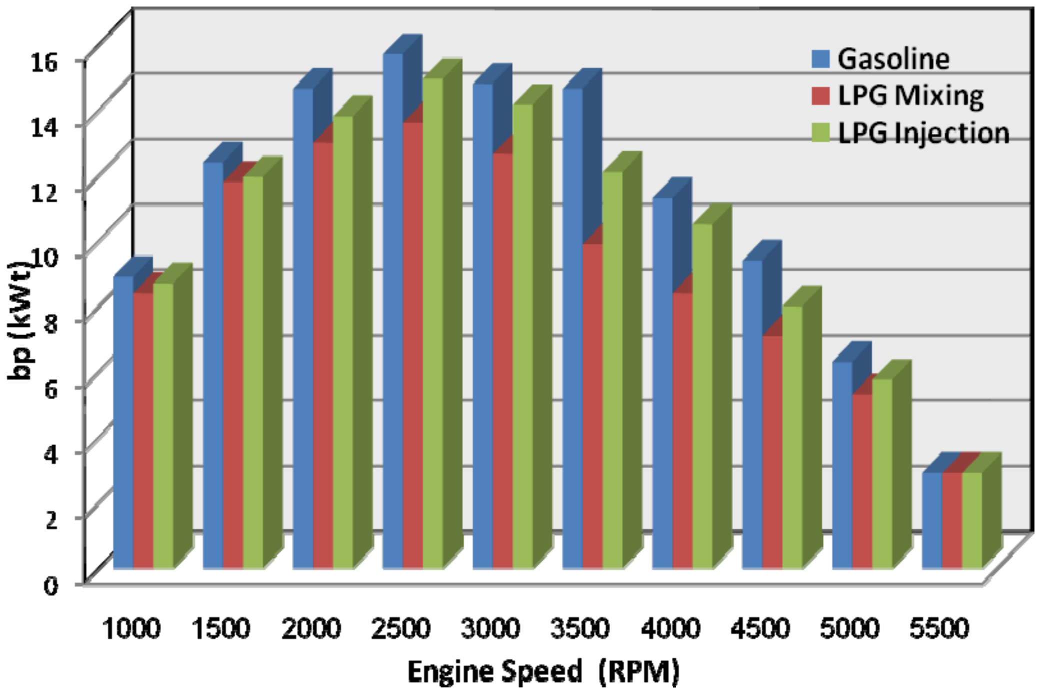

Figure 6. Relation between brake power and engine speed at different torques

Figures 3-5 illustrate the relation between bsfc with engine speed at different torque (20, 40 and 50) Nm. Brake specific fuel consumption with injected LPG is, at every speed and almost for different torque values between 20% and 30% lower. The gaseous form of the dosed LPG allowed the reduction of the enrichment needed for idling stability and therefore reducing idling fuel consumption and operating cost and the better mixing of injected fuel with air also decrease the bsfc.

Figure 6 shows full capacity of operation with LPG and gasoline with a small decrease of power with LPG, probably due to the loss of volumetric efficiency when using a gaseous fuel due to the intake air displacement (lower density for gas). Although the maximum power developed by the injected LPG is almost the same as in gasoline , its performance over the whole speed range is about 7% lower (compared with other results in [7], test results show 6 % less power with LPG than with gasoline).

4.2. Engine Emissions

Figures 7-10 show the level of measured emissions (CO, CO_2, HC, and NO_x) against brake power with fixed engine speed (1500 RPM) and air-fuel ratio.

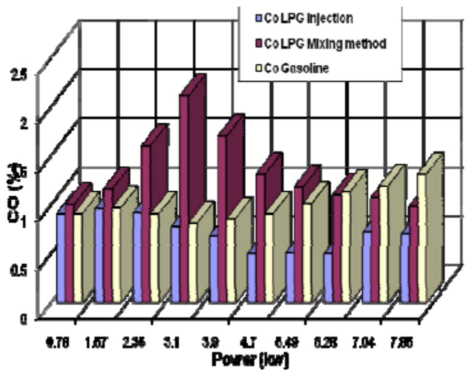

Figure 7. Level of CO

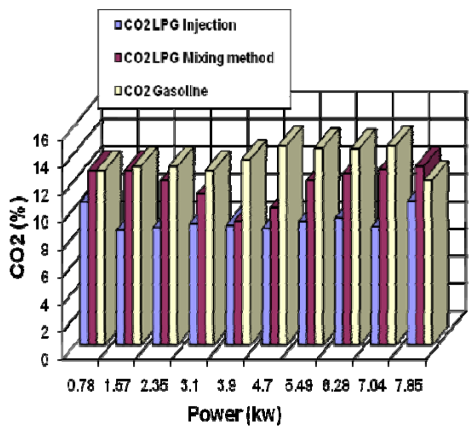

Figure 8. Level of CO_2

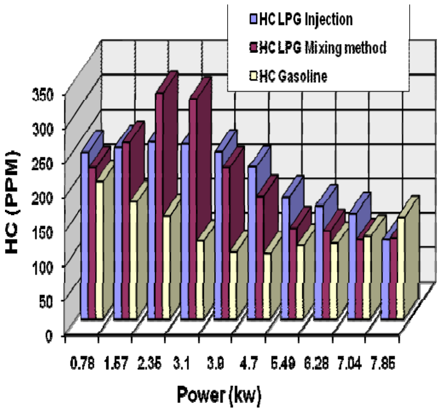

Figure 9. Level of HC

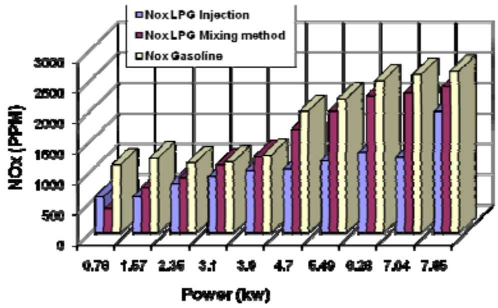

Figure 10. Level of NO_x

CO emissions are controlled by air-fuel ratio, they seem to be also influenced by the kind of fuel. LPG emissions at the same air-fuel ratio were lower. This may be due to the better mixing obtained by gaseous fuel dosification and due to the higher cylinder-to-cylinder uniformity achieved and which also affect the formation of CO_2.

The difference between LPG and gasoline emissions is quite low, may be due to the fact that the controlling characteristic is engine design, with the distribution arrangement and combustion chamber design being of crucial importance. In fact, the longer valve overlap period at low speed may explain the higher HC emissions obtained and may also explain the fact that LPG emissions at low speed are higher than gasoline emissions. The reason could be the higher inertia of gasoline liquid droplets and thus their lower tendency to follow intake air in its bypass path. At higher engine speed, when ram tuning effects control gas motion during the overlap period, LPG HC emissions are comparable or even lower than gasoline emissions for the same engine. The fact of LPG CO emissions being much lower on the overall speed range may support this idea because not much HC may be thus be expected to come from an incomplete combustion.

For the formation of NO_x compounds, the presence of oxygen and high temperature will lead to high NO_x formation rates. At low engine speed, there is no sufficient oxygen for more NO_x emissions formation (lower excess air levels starve the reaction for oxygen, and higher excess air levels drive down the flame temperature, slowing the rate of reaction) and as it is known that the CO reduction is normally coupled with an increase in NO_x production.

5. Conclusion

It can be concluded that the use of LPG instead of conventional gasoline will mean a reduction in low engine brake power, brake specific fuel consumption and pollutant emissions, with loss of power (7%). Also, a reduction in brake specific fuel consumption of about 20%-30% was found, moreover no highly rich mixtures were needed for stable idling operation.

References

[1] Poulton M.L, “Alternate Fuels for road vehicles” Computational Mechanics publications, Ashurst, Southampton, UK, 1990, 84-85, 94-95.

[2] M.Ihsan Karamangil,”Development of the Auto Gas and LPG powered vehicle sector in Turkey: A stastistical case study of the sector for Bursa, ”Vol. 35, No. 1. 2007, 640-649.

[3] .MckenzieC.h.Lim, GodwinA. Ayoko, LidiaMorawska, ZoranD.Ristovski, E.Rohan Jayaratne, Serge Kokot”, A comparative study of the Elemental Composition of the Exhaust Emissions of Cars Powered by Liquified Petroleum Gas and Unleaded Petrol”Vol 40, No. 17, 2006, 3111-3122.

[4] R.R.Saraf,Dr.S.S.Thipse,Dr.P.K.Saxena, ”Experimental Performance Analysis of LPG/Gasoline Bifuel Passenger Car Engines”, 2007, SAE -01-2132.

[5] http://www.chilterngascars.co.uk/cars/lpghowb.htm

[6] R.R.Saraf,Dr.S.S.Thipse,Dr.P.K.Saxena,

”Case study on Endurance test of LPG Automotive Engine”, 2008, SAE -01-2756.

[7] J.E Sinor Consultants Inc, The Clean Fuels Report, Volume 4, No. 5, 1992.