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COMPARATIVE STUDY OF A DUAL FUEL SYSTEM SPARK IGNITION ENGINE

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ABSTRACT

Considering the importance of alternative fuels in IC engines for the safety of the environment, liquefied natural gas has been extensively employed in SI engines. In this regard, a comprehensive analysis has been made of the engine performance, and emissions rate, using PMS and LPG at different operating conditions for the economic analysis were all made. it was seen that using LPG there was an increase in thermal efficiency of 0.75%, a relative efficiency of 0.67%, and an overall efficiency of 0.76% but a reduction in the mechanical efficiency of 0.83% while in PMS fuel there is an increase in mechanical efficiency 0.88% but a reduction in Thermal efficiency 0.39%, Relative efficiency 0.47%, Overall efficiency 0.57%. The key parameters of the engine performance like brake power, engine efficiency, engine torque, and specific energy consumption were investigated at 80% and engine speed 1590-1650 range of r/min. For the sake of emission tests, speed was varied uniformly by varying load at constant throttle. Furthermore, the engine was run at load and off-load. Although liquefied natural gas shows a decrease in brake and specific energy consumption and emission content performed relatively better in the case of brake power.

KEYWORDS: Engines, Fuels, Efficiency, Liquefied natural gas (LPG), Performance, Premium motor spirit (PMS).

INTRODUCTION

The investigation of internal combustion ignition engines can't be overemphasized because of their handiness in the existence of man and addressing different necessities concerning transportation. However, the internal combustion engine is an engine that changes chemical energy into a nuclear power (heat energy), and later in the combustion chamber, it changes over the same nuclear power into mechanical energy. Significantly, there are two kinds of internal combustion engines. Are the rotary and reciprocating engine, and the most usuallyutilized are the reciprocating internal combustion engines since they have cylinders that move in a chamber, goes through a straight movement, and force is communicated through an interfacing bar to drive the shaft, and has multiple or more chambers which work on four strokes (four- cylinder) development with two goals for each cycle or a two-stroke cycle (two cylinders) development with one goal for each cycle.

In recent engines the advancement of dual fuel technology is motivated by emission guidelines that require explicit cutoff points be met for toxins delivered into the environment, the improvement is additionally persuaded by the expected investment funds on task costs for dual fuel engines compared with diesel engines. Consequently, numerous diesel engines are changed over to run with vaporous fuels like gaseous petrol and hold positive highlights of diesel activity. It is bountiful and eases and lessens outflows of both NOx and PM. This research is centered on a comparative study of a dual-fuel system spark ignition engine.

AIMS AND OBJECTIVES

This thesis work aims to carry out the comparative study of a dual-fuel spark ignition engine using PMS and LPG as working fluids under certain experimental conditions. In other to achieve this aim, the following objectives were considered:

- Compare the economic analysis of both fuels.
- Determine the cost of maintaining the dual fuel generator for both fuels.
- Use LPG and PMS Fuel to determine engine performance.
- Analyze the exhaust gasses emissionsusing an exhaust gas analyzer

Statement of Problem

The increase in fuel price and increase in strict emission regulations are concerns for manufacturers and operators of spark ignition engines. By converting the spark ignition unit to dual fuel operation and utilizing lower-cost natural gas, both lower fuel costs and lower emissions can be achieved. However, the cost savings through fuel displacement and emission reductions need to be quantified. Thus, the purpose of this work is to address the challenges associated with dual fuel spark ignition engines, to improve efficiency and obtain better control of the exhaust emissions. Therefore, the detailed analysis of combustion is one of the most important key factors to determine an engine's efficiency. In the course of this research, liquefied petroleum gas and premium motor spirit will be used in the analysis of this work.

SCOPE OF STUDY

This work is limited to

- The study described in this project is divided into experimental and theoretical work. The conversion kits and procedure are provided for the dual fuel engine while the experiment willbe carried out in an off-university laboratory.
- Analyze dual fuel spark ignition engines.

LITERATURE REVIEW

2.1 Dual Fuel Engine

Alternative fuel innovation is a promising perspective as far as decreasing the outflows from fuel engines. The transformation of such an engine to chip away at gas fuel (spark ignition) or diesel (compression Ignition) and other related powers (Wan, 2014). The most utilized gasses in diesel or sparkle engines are petroleum derivatives, which are liquefied petroleum Gas (LPG), liquefied natural gas (LNG), and compressed natural gas (CNG) which are utilized for explicit vehicles dependent on their capacities (Wan, 2014). Fig. 2.1 shows the diagram of LPG- Petrol Dual Fuel Spark Ignition for PN Reduction. Dual fuel engines have been so huge in addressing the necessities of Europe's energy and natural difficulties. as indicated by the investigations done by LPG European Association which showed a more noteworthy job for double fuel engines in Europe will have a more prominent potential for success in forestalling the emanation of million tons of CO_2 and will likewise diminish the fixation level of various unsafe air pollutants, especially in territories that is exceptionally industrialized (Wan, 2014).

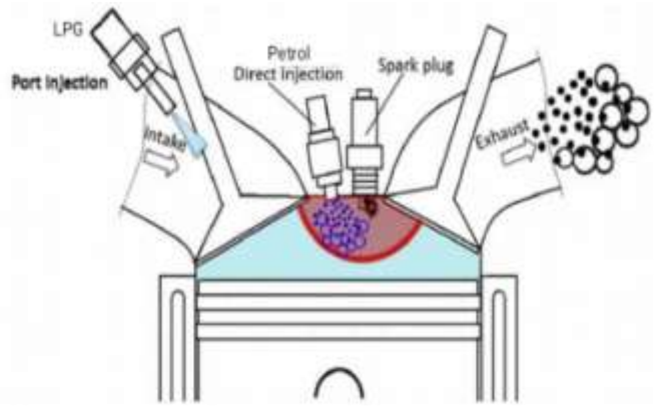

Fig. 2.1: Schematic of LPG-Petrol Dual Fuel Spark Ignition for PN Reduction (Liu et al., 2015).

2.2 Dual Fuel Operation

In dual fuel activity, ignition preferably comprises a diesel fuel flame advancing through a lean premixed air and vaporous fuelcombination which is locally homogeneous. Fig.

2.3 For a dual fuel operation signifies the premixed air and vaporous fuel burn within the sight of the diesel flame and a premixed flame is initiated by the diesel flame and proliferates through the excess air and vaporous fuel blend. During the compression stroke, the premixed combination's temperature and pressing factor are extraordinarily expanded, shaping the pre- ignition response to the environment. During this stage, fractional oxidation items can shape toward the finish of compression to actuate diesel fuel ignition and combustion. The diesel flame front is extraordinarily impacted by disturbance, twirl, and crush inside the cylinder. The ignition interaction of a dual-fuel engine is depicted in five phases. The information is taken on a single- cylinder pre-chamber diesel engine with a pump line-injector mechanical diesel injection system. In the combustion phases of a dual fuel engine, after the diesel fuel is injected at point, a longer ignition delay is observed in dual fuel ignition than in ordinary diesel engines because of the decrease in oxygen fixation coming about because of the acquaintance of flammable gas with the intake charge. The premixed ignition stage in dual fuel is more slowed compared with ordinary diesel premixed combustion because the dual fuel engine is infusing a more modest measure of fluid fuel, hence a more modest measure of the burning blend is added to the fuel, which shows a decrease in pressure until it rises. As the essential fuel (premixed air and petroleum gas fuel) defer period, the genuine combustion of the flammable gas fuel beginning with the flame propagation initiated by the spontaneous liquid fuel ignition leads to diffusion combustion.

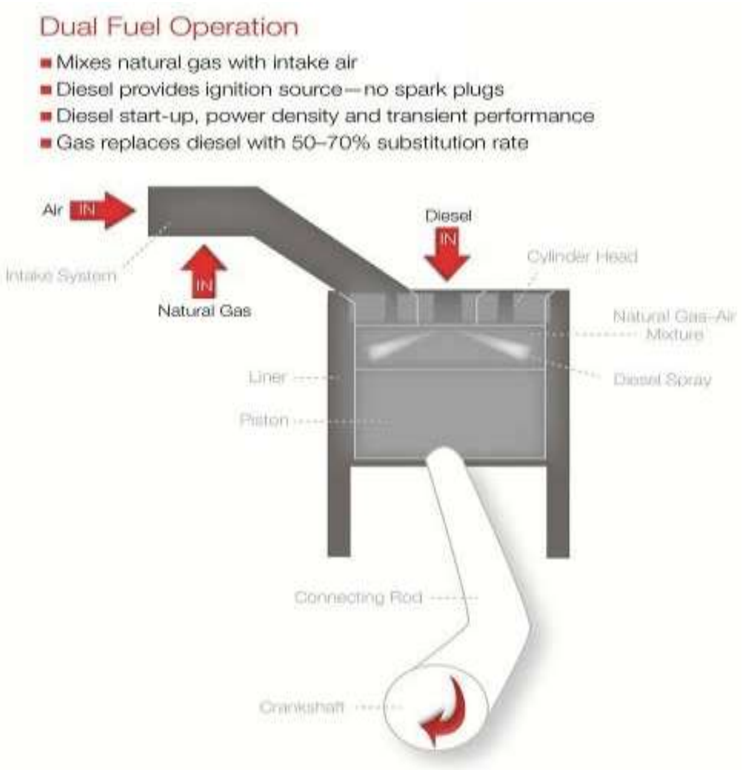

Fig. 2.2: Dual Fuel Operation (Cummins, 2021).

2.3 Biodiesel

Haik et al., (2011), tried microalgae fuels in a Ricardo diesel engine and examined the components influencing the in-cylinder pressure wave and greatest in-cylinder pressure rise. Petroleum diesel (PD), unrefined microalgae oil, and biodiesel. The examination uncovered that Biodiesel microalgae oil and biodiesel decreased the engine performance and increased engine noise.

Wahlen et al., (2012) surveyed engine performance and emission using PD and biodiesel from soybean, microalgae (Chaetoceros gracilis), microscopic organisms, and yeast. Be that as it may, the examination was conducted under restricted working conditions and the consequences of the fumes gas outflows were just tried under no-load conditions at 3500 rpm. Tüccar and Aydın (2013), tried microalgae biodiesel in diesel engines and announced that microalgae biodiesel can be utilized as elective fuel in CI engines with fewer fumes gas discharges. Chen et al., (2012), revealed that MCP-B100 (from the Solley Institute) has physical and substance fuel properties that fulfill the ASTM guidelines. There was an insignificant difference in the maximum in-cylinder pressure between biodiesel and PD. A few examinations have revealed an increment in NOx with biodiesel fuel though others have announced a decrease.

MATERIAL AND METHODOLOGY

Tools/Model Used for The Dual Fuel Experiment

Engine test bed: This is a facility used to develop, and characterized engine operation, andmeasure several variables associated with theengine operation.

Gas cylinder: A pressure vessel for storage and containment of gasses at above atmospheric pressure.

Stopwatch: This is a timepiece designed to measure the interval of time that elapses betweenits activation and deactivation.

Weighing Scale: It is a device used to measure weight or mass.

Portable gas analyzer: Is used to measure the concentration of various gasses, such as NOX, CO2, etc.

Gas regulator: It is used to reduce high-pressure gas in a cylinder or process line to a lower usablelevel when it passes from the cylinder to the burner.

Pressure hose: It is used to transfer compressedair and gasses from one point to another.

Experimental Procedures

Initial measurements of the empty LPG cylinder will be taken to ascertain the cylinder is empty. The fuel tank will also be checked. The empty gas cylinder will be placed on a weighing scale and then fixed to the engine using a pressure hose which will be linked to the engine via a hybrid carburetor. The engine will be allowed to run at about 60% engine load until 1kg of LPG is consumed, and an exhaust gas emission analysis will be carried out using an exhaust gas analyzer. Then the runtime is measured at this loading condition and the various gas emissions will be noted. This procedure will be carried out three times to ensure consistency in experimental results. The PMS fuel will be measured while considering the amount of 1kg of LPG cost. In other words, the same amount which was used topurchase 1kg of LPG will be used to purchase anequivalent of PMS. And the same 60% ON-loading condition done for the LPG will be conducted for the PMS fuel and runtime recorded as well as the exhaust gas emissions. A 0% NO-loading test will also be conducted on the LPG and PMS and the running time checked with the exhaust gas emissions checked. The results will be plotted on a graphical representation of Originengineering software.

The following methods will be adopted to achieve our goals.

Engine and Instrumentation

The dual-fuel engine experiments will be performed on a single-cylinder, four-stroke spark-ignition engine. The engine specification will be specified. The fueling modes will be used separately. The engine will be coupled to a test bed and will maintain a constant speed regardless of the engine torque output.

Test Fuels

In this study, two fuels will be used. The fuel properties will be listed and considered in Table 3.2

Liquefied Petroleum Gas (LPG)

Liquefied Petroleum Gas (LPG) is a hydrocarbon mixture, also the essential ingredient of LPG is commercial propane and butane, with portions determined by the seasons and the field of use. LPG can be liquefied at normal temperatures using a pressure of approximately (8.5 to 9.0 in) the atmosphere. It is characterized by being free of water and hydrogen sulfide, and it is always under vapor pressure. This pressure force is affected by environmental temperatures, as the vaporization pressure for propane and butane are not uniform, and also not equivalent in temperature. Consequently, the mixing ratios of this vapor influence the total liquefied petroleum gas for pressure and heat energy.

Premium Motor Spirit (PMS)

Premium Motor Spirit is a fuel used in an internal combustion engine with spark ignition, designed to run on petrol (gasoline) and similar volatile fuels. Mostly petrol engines, the mixture of air- fuel ratio before compression is performed during an intake stroke (although some modern petrol engines now use cylinder-direct petrol injection). The mixture is usually done in a carburetor, but now it is done by an electrical actuator called a fuel injector, except in a small petrol engine, the amount does not justify additional efficiency. The process in a petrol engine differs from a diesel engine during the combustion process and uses spark plugs to ignite the combustion process. In a diesel engine, only air is compressed and heated, and the fuel is sprayed into high-temperature air at the end of the compression stroke, and self- ignition occurs.

3.5 MATERIALS TO BE USED FOR THE ANALYSIS

3.5.1 Working Fluids

The working fluids that will be considered during the cause of this research are; unleaded gasoline, liquefied petroleum gas (LPG), and air. Some properties of the fluids to be considered are shown in Table 3.3

Table 3.1: Fuel Specification.

Fuel Properties	LPG	PMS	Air
Specific heat ratio (k)	**1.13**	1.3	**1.4**
Gas constant (R) (kJ/kg. K)	0.189	NA	0.292
Specific heat capacity at constant pressure (kJ/kg.K)	1.67	**2.4**	**1.01**
Specific heat capacity at constant volume (kJ/kg.K)	1.48	**NA**	**0.718**
Density (kg/m^2)	530	**756**	**1.225**
Auto ignition temperature (^{o}C)	501	**250**	**NA**
Air-fuel ratio	15.45	**14.2**	**NA**
Calorific Value (KJ/Kg)	46100	**43932**	**NA**
Octane number	105	**95**	**NA**

Other Materials Used

- Pressure hose
- Engine test bed
- Pressurized Gas Cylinder
- Gas Regulator
- Fuels; LPG and Petrol
- Weighing Scale
- Hose Clips
- Stopwatch
- Exhaust gas analyzer

Assumptions for Dual Fuel Engine

- The combustion chamber consists of PMS or LPG fuel at the point of running each fuel, the temperature is uniform, and the fuel composition; the pressure is uniform in the combustion chamber since it's a single cylinder.
- The engine runs each fuel per time.
- The engine uses a hybrid carburetor.
- The engine is assumed to operate for 6 hours per day and 2160 hours in a year.
- The PMS fuel zone refers only to the carburetor upon which a droplet of fuel is assumed to vaporize instantly.

- The unburnt fuel is assumed to consist of Air, Exhaust Gas residual, and Gaseous fuel in their measure proportion.

RESULTS AND DISCUSSION

In this proceeding chapter, Experimental research and result analysis carried out in different fuels; LPG and PMS will be presented to determine engine performance in a Dual fuel generator. This chapter will be focused on a comparison of engine performance and fuel consumption, engine speed, energy price, cost-effectiveness, specific fuel consumption, engine torque, and engine efficiency.

COMPARISON OF ENGINE PERFORMANCE AND FUEL

Consumption

Like all other internal combustion heat engines, fuel combustion of LPG and expansion in the closed-cylinder spark ignition engine is the basic mechanism for its power generation during engine operation. Therefore, the performance of the engine is affected by the engine design, working fluid, mechanical properties of the engine component, and combustion behavior of the fuel LPG and PMS. The ignition of LPG causes delay once the spark is initiated, which causes a bigger flame kernel and consequently the flame expansion to a larger volume of the combustion chamber which releases a lesser hydrocarbon content of emission. This expansion rate is further accelerated by the burning velocity. Thus, the relatively unburned mixture of hydrocarbon and NOx is compressed outwards by such an increase in the combusted volume. The density of the non-reacted blend is greater than that of burned gasses even in the vicinity of the flame front, increasing the pressure inside the cylinder. So, this compression heating raises the temperature of the unburned mixture which tingles out when the piston changes toward the outer dead center. Leaner burning velocity is a valuable parameter to analyze the premixed flame in terms of the net rate of reaction. The major fraction of LPG consists of inert gasses that is, methane, CO2, and N2 which act like diluents to reduce the flame temperature due to which LPG burns with a relatively lower laminar burning velocity. A continuous increase in the exhaust gas temperature can be expressed in engine speed due to the movement of the piston. However, PMS showed comparatively higher temperatures (12.93%) over the designated range of revolutions per minute (1500–3000). Unaltered ignition timing is one of the reasons for the reduction in BP and temperature for LPG fuel. In addition, low flame velocity and air displacement are the other factors for the decrease in BP for LPG as it mostly comprises methane (CH4), which has the lowest flame velocity among hydrocarbons. Hence, the BP is decreased due to unwanted heat transfer during prolonged combustion of LPG when unburned hydrocarbons move out with the exhaust gas. A similar trend was shown by both fuels (initially a decrease, then an increase in the value of BSEC with the increasing speed). However, LPG showed an average reduction of 7.94% incomparison to PMS. This decline can be attributed to the passive burning and higher energy potential in LPG. The increase in the fuel consumption for the BP produced is because energy loss to the water jacket is higher at a lower speed and fractional friction power increased at ahigher speed.

Engine Torque

Engine torque is the turning and twisting force acting over the shaft during the rotation of the crankshaft. It is a tangential force acting over the motor shaft due to the interaction between current and magnetic field placed perpendicular to each other. It can be observed in the chart below that the torque is also slightly higher for an engine running on PMS than for an engine running on LPG. The engine running PMS had a torque of 3.22Nm and the engine running

LPG had a torque of 3.11Nm. Values are obtainedusing the formula;

$$T = \frac{EMEP \times Volume\ displacement}{2\pi \times nr}$$

Where nr is number of crankshaft rotations for a complete engine cycle for a 4-stroke engine

$$PMS = \frac{9.2 \times 4.4}{2 \times 3.142 \times 2} = \frac{40.48}{12.568} = 3.22Nm$$

$$LPG = \frac{8.9 \times 4}{2 \times 3.142 \times 2} = \frac{39.16}{12.568} = 3.11Nm$$

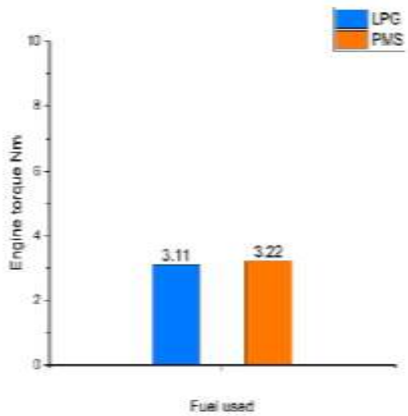

Fig. 4.1: Engine torque for LPG and PMS.

Energy Price and Cost Analysis

To analyze the economic cost of running theengine with both fuels, the SFC results will be utilized. The analysis is based on the Fuel pricing data obtained from the Nigerian National Petroleum Corporation (TOTAL). TOTAL retail outlets retail LPG for $0.97/kg while PMS is sold for $0.40/liter, converting to its mass equivalent we arrived at $0.54kg. For an easy and effective comparative analysis, $0.97 worth of PMS was measured and used to run the cost-effectiveness test, and 1kg of LPG which also cost $0.97 was also measured and used as well. The PMS fuel lasted for about 90minutes and LPG for about 120 minutes with Off-loads and 53 minutes and 85 minutes respectively under 60% loading. It is observedthat engines fueled by LPG will lead to savings in terms of cash spent on energy purchases. At the end of the experiment, we discover that LPG of1kg lasted longer than PMS with 30 minutes difference.

Table 4.1: Data analyze the cost of PMS, LPG Fuels and lubricating oil in dual engine test bed.

Fuels	Quantity	Cost ($)
LPG	1kg	0.97
PMS	0.737kg	(1 0.54 Litre)
Lubricating Oil	1 Litre	2.5

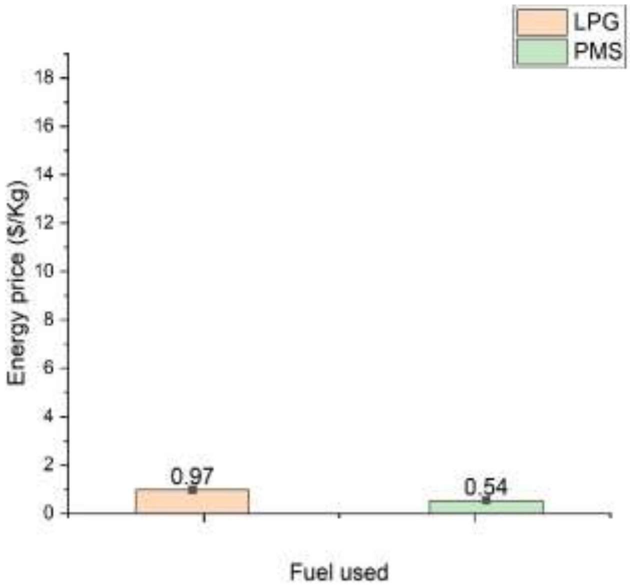

Fig. 4.2: Energy price for LPG and PMS.

To further analyses economics of both fuels, the engine was assumed to undergo 2160 hours of operation in a year. Estimates of its routine maintenance, parts purchase etc. was evaluated for this period. The Annual Engine cost is shown in Figure 10 above. Result shows that the cost ofrunning the engine for 2160 hours in a year is about 26% higher for PMS when compared to LPG.

Generator operations: 6 hours a day.
No. of days in a month's: 30 days
Therefore 6×30=180 hours.
180×12=2160 hours of operation in a year.

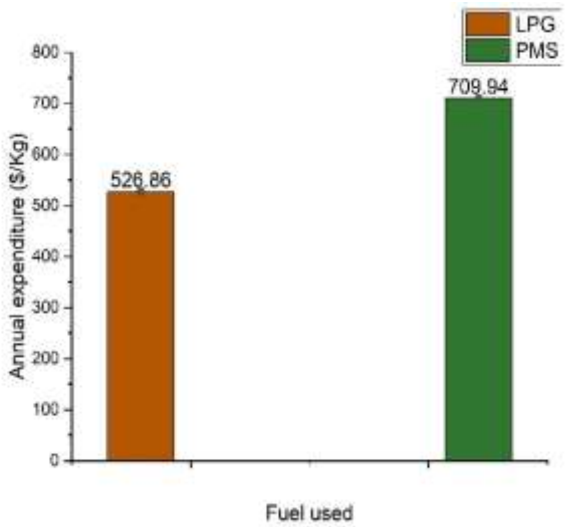

Fig. 4.3: Annual engine cost for 2160 hours ofoperation.

4.5 Loading Condition on LPG and PMSFuel

Table 4.2: On-Load LPG.

S/N	TIME (Min)	LPG USE D	APPLIANCE S	WAT T
1	30	0.6kg	Refrigerator, air condition	2000
2	60	0.9kg	Hot plate, microwave	2700
3	90	1.2kg	2Refrigerator, air condition	2800
4	120	1.8kg	Electric stove, air condition, microwave	3700

Table 4.3: On-Load PMS.

S/N	TIME (Min)	PMS USE D	APPLIANCE S	WAT T
1	30	1 litre	Refrigerator, air condition	2000
2	60	2 litres	Hot plate, microwave	2700
3	90	2.2 litres	2Refrigerator, air condition	2800
4	120	4 litres	Electric stove, air condition, microwave	3700

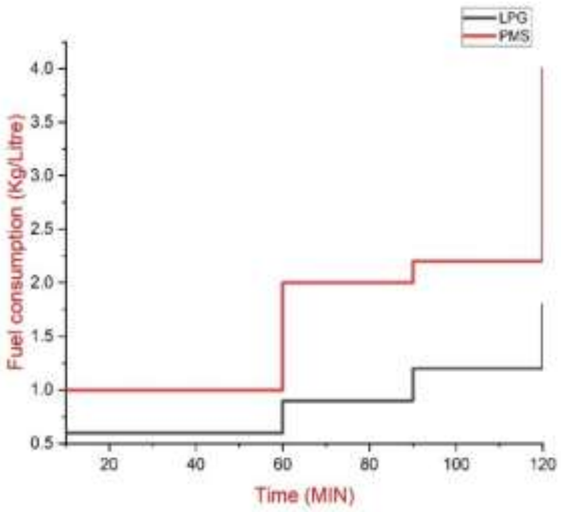

Fig. 4.4: Fuel consumed On-load for LPG andPMS.

Using LPG fuel with load the graph in figure fig. 4.8 indicate that in the different time interval there is little amount of LPG consumed when the engine is loaded in different loading condition. There is also increase in Relative efficiency, increase in overall efficiency, increase in Thermal efficiency but there is decrease in mechanical efficiency. Why using PMS fuel, the graph indicates that in the different time interval using PMS consumed more fuel with load more than LPG there is also increase Mechanical efficiency but there is decrease in Thermal efficiency, decrease in Relative efficiency, decrease in Overall efficiency.

4.6 Off Load Condition on LPG and PMS

4.5 Table 4.4: No-Load LPG.

S/ N	TIME LPG USE (Min D)	APPLIANCES	WAT T
1	300.09kg	Nil	Nil
2	600.6kg	Nil	Nil
3	900.9kg	Nil	Nil
4	1201.2kg	Nil	Nil

Table 4.5: No-Load PMS.

S/ N	TIME PMS USE (Min D)	APPLIANCES	WAT T
1	300.9 litres	Nil	Nil
2	601.8 litres	Nil	Nil
3	902 litres	Nil	Nil
4	1203.5 litres	Nil	Nil

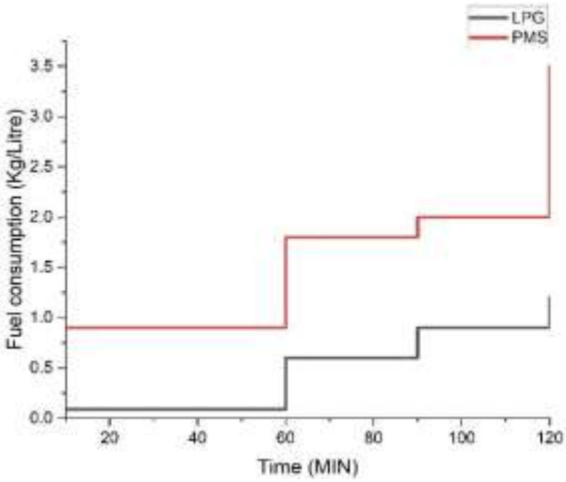

Fig. 4.5: Fuel consumed off-load for LPG andPMS.

The analysis carried out so far in the dual fuel generator indicate in both graph shows that LPGtend to perform better and fuel tend to last more in LPG than PMS. Efficiencies seems to be morein LPG compared to PMS fuels.

Economic Benefit and Effectiveness Analysis

As the base of comparison, emission or the only improvement of fuel quality to meet Nigeria fuelstandards as a basis. By following emissionstandard alone, it will result to reducing sulfurlevels to below 500 parts per million (PPM), thebenefits are: substantial reduction in health costs and productivity losses which are estimated at more than #38,963 billion Net Present Value(NPV) over a period of 2005-2030. This optionalso provides a NPV in fuel savings of #71,395billion between 2009-2030 (Anderson 2012).

The policies of the use of LPG for power generation, the introduction of hybrid technology carburetor, and the use of dual fuel for local generators result similar figures. However, the use of LPG for electric power is the largest economic gain, among this the use of dual fuel for generators is the largest policy for fuel saving.

We found that a consistent direction between neteconomic benefit matter or fuel saving concern except between the use of LPG and the use of dual fuel. However, we can conclude that among those policies, standardize fuel efficiency will give best benefit, then the improvement of electricity supply with generators is becoming second best option. Furthermore, we can elaborate and carefully compare between the useof LPG and PMS for electricity generation, the introduction of hybrid technology, and the use ofdual fuel for power generation. Each of this has drawn us back to further research; the use of

LPG requires high cost for converter and availability of gas supply. The introduction of hybridtechnology makes hybrid generator prices more expensive and it is estimated odds USD 100 million compared to single fuel generators. The use of dual fuel has some weaknesses because this policy is still unsubsidized and it makes dual fuels more expensive.

Concerning cost effectiveness, we find that the use of LPG is the most effective in cost. The introduction of hybrid technology and the provision of small generators are the best effective. We conclude that the provision of dual fuel generators using LPG is the best option by considering the net economic gain, fuel saving and the least cost to reduce emission per million ton.

Economic Aspect of LPG and PMS

- Cheaper than petrol: The cost per litre, both in Spain and in Europe is 50% less than of PMS or diesel. As consumption increases around 10% due to the difference in densities. The net economic saving is between 40 to 45%.
- Greater autonomy: The vehicles adapted to LPG multiplies its autonomy by two by installing a second tank. PMS remains unchanged and the driver can used both fuels interchangeably. The average autonomy of a vehicle with LPG is 500 or 600 kilometres, double if we also use PMS tank.
- 68% reduction in NOX emissions and 15% CO2 if compared to PMS and 99% particles, 96% NOX 50% noise level and10% CO2 if compared in diesel or biodiesel.
- LPG vehicles are catalogued with a green ECO vehicle label just like electric one to allow their circulation in restricted urbanareas. They are also benefits from discounts on road and registration taxes.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study is focus on dual fuel engine performance characteristic using LPG and PMS fuels under different operating conditions. Experimental results showed that PMS produced a slightly better Engine Mean Effective Pressure and Engine Torque (hence engine power) relative to LPG. Specific Fuel Consumption, Engine Efficiency, Energy Pricing, Annual Energy Expenditure, Cost and Exhaust emissions were all better when LPG was used as the Engine Fuel relative to PMS. In conclusion, LPG was considered the better fuel due to its environmental friendliness and the 25% cheaper fuel it offered for fairly similar engine power. In terms of the Overall efficiency, LPG performed better with 76% relative to 57% for PMS fuel. It is important to say that LPG results could have been better if the engine wasn't tailored to PMS. Recommendation

The following recommendations are proposed totake this research further

- Measuring devices for pressure, temperature, flame distribution in combustion chamber, etc. should be acquired to ensure detailed experimentalresults are obtained.
- Acquisition of a bigger Gas analyzer forexhaust gas analysis will help in quantifying the emissions from the engines when running on different fuels. An analyzer for CO2 should be acquiredto quantify CO2 emissions.
- A dedicated automobile engine as well as a big generating plant should be used for further research into this area.
- Nitrogen should be used in cleaning the hybrid carburettor before switching to another fuel.
- Dynamometer should be use for further research in other to measure the different mechanical forces.

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