

Comparative Analysis of Engine Efficiency and Emission Using Premium Motor Spirit (PMS) and Liquefied Petroleum Gas (LPG) in Spark Ignition Engines

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Abstract The increasing global demand for energy, coupled with growing concerns about climate change, air pollution, and energy security, has highlighted the need for sustainable and environmentally friendly transportation solutions. Spark Ignition Engines (SIEs), which are widely used in vehicles, are significant contributors to greenhouse gas emissions and air pollution. Therefore, exploring alternative fuels that can reduce the environmental impact of SIEs while enhancing their efficiency is crucial. This study investigates the performance and efficiency of a Spark Ignition Engine (SIE) when powered by Premium Motor Spirit (PMS) and Liquefied Petroleum Gas (LPG) separately, evaluating Key parameters analyzed include torque, power output, thermal efficiency, volumetric efficiency, brake mean effective pressure (BMEP), and fuel consumption. Experimental tests and simulations were conducted to compare engine performance under varying conditions. The results indicate that LPG delivers superior thermal efficiency and lower emissions than PMS, supporting its viability for cleaner energy applications. The study underscores the potential benefits of LPG-powered.

Keywords: Premium Motor Spirit (PMS), Liquefied Petroleum Gas (LPG), Engine Efficiency, Spark Ignition Engine (SIE), Thermal Efficiency, Emissions

I. Introduction

Energy is the ability to perform work or generate heat through the combustion or use of fuel. It is the foundation of modern civilization, enabling our everyday tasks, fuelling industries, and fostering technological progress [1]. The availability of energy is a crucial global indicator of industrialization, economic expansion, and sustainable development [2]. Petroleum Motor Spirit (PMS), commonly known as gasoline, is a product refined from crude oil. Its rising cost is attributed to the dwindling reserves of crude oil. Additionally, the finite nature of fossil fuel reserves is unlikely to meet future energy]

demands, with the challenge of fuel scarcity projected to become increasingly critical [3]. Alternative fuels can be categorized into industrial gasoline, alcohol-based fuels, gaseous fuels, and other types [2]. The search for alternative fuels to replace conventional PMS in Spark Ignition Engines (SIEs) is gaining momentum due to environmental concerns and economic considerations. Liquefied Petroleum Gas (LPG), a cleaner and more energy-efficient fuel, has emerged as a promising alternative due to its lower carbon emissions and higher calorific value. This study aims to conduct a comparative analysis of engine efficiency when using PMS and LPG as fuels in a SIE. The focus is on understanding their performance in terms of power output, thermal efficiency, and fuel consumption, which are critical indicators of engine efficiency [2, 4].

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Previous studies have extensively explored the characteristics of PMS and LPG as fuels for SIEs. According to Li, et al. [5], LPG has a higher-octane rating than PMS, which leads to improved combustion efficiency and reduced knocking. Other studies have shown that LPG produces fewer greenhouse gases and particulate matter than PMS, making it a more environmentally friendly option [6, 7]. Extensive research has explored how the performance and emission characteristics of PMS and LPG vary with different fuel types. Studies have shown that the choice of fuel significantly impacts engine performance metrics and emission profiles [8, 9].

These impacts are heavily influenced by technological advancements, engine configurations, and the operational parameters of machinery and vehicle propulsion systems [10]. Nguyen, et al. [6] reported studies on the performance and emission characteristics of a spark ignition engine operating on Liquefied Petroleum Gas (LPG). The findings revealed that LPG usage resulted in reduced specific fuel consumption and a significant decrease in CO and CO₂ emissions. On the other hand, there was no notable loss in energy output, the study observed an increase in NO_x emissions.

Şöhret and Gürbüz [4] conducted a comparative study on the performance and emissions of a spark ignition engine operating on LPG and unleaded gasoline. The engine was modified to run on LPG, and the results indicated a reduction in engine torque and power, as well as an increase in brake specific fuel consumption following the conversion and the application of a 7mm valve lift. Despite these changes, LPG use resulted in improvements in CO and HC emissions, though NO_x emissions increased. The study also noted enhanced engine performance

with LPG, which was attributed to a greater intake mixture per cylinder. Iodice and Cardone [11] reviewed the impact of using liquefied natural gas as the primary fuel in a heavy-duty diesel engine, with a small amount of diesel used for ignition. The study found that dual fuel operation led to higher specific fuel consumption and lower thermal efficiency compared to running the engine solely on diesel. However, it also resulted in increased emissions of total hydrocarbons and carbon monoxide, while emissions of nitrogen oxides (NO_x) and carbon dioxide (CO₂) were reduced. Taha, et al. [3] and Şöhret and Gürbüz [4] studied a four-stroke spark ignition outboard engine powered by LPG, which was adapted to operate on both LPG and gasoline. Two different LPG operating methods were tested: one using engine-generated vacuum for stable carburetion, and the other involving direct fuel injection of LPG. The results revealed that when LPG was directly injected, brake power, engine torque, and brake-specific fuel consumption were lower compared to gasoline. On the other hand, the vacuum system led to higher brake power, although engine torque remained unchanged. Emissions of CO, CO₂, and NO_x were lower in LPG mode compared to gasoline, while hydrocarbon emissions were higher. However, the performance in terms of fuel consumption, engine power, and efficiency remains a critical parameter for determining the feasibility of LPG as a widespread alternative.

The increasing concern about climate change, energy security, and air pollution has led to the search for alternative fuels that can reduce greenhouse gas emissions and improve engine efficiency. Spark ignition engines, which are widely used in transportation, are a significant contributor to emissions. This study focuses on

comparing the engine efficiency and emissions of Spark Ignition Engines using PMS and LPG. The justification for this study lies in the need to explore alternative fuels that can reduce emissions and improve engine efficiency. The objectives of this study are to: (1) compare the engine efficiency of Spark Ignition Engines using PMS and LPG (2) evaluate the emissions characteristics of both fuels, and (3) determine the most environmentally friendly and efficient fuel option for Spark Ignition Engines. By achieving these objectives, this study will contribute to the development of sustainable transportation solutions.

II. Materials and Methods

A. Materials

i. Fuel

Premium Motor Spirit (PMS) and Liquefied Petroleum Gas (LPG) were the primary fuels used in this study. The PMS was sourced from Bovas filling station, Akobo, Oyo state on 14th march, 2004 at 10:35am. All PMS samples were taken from the same batch to maintain consistency. LPG was obtained from Gasland gas station Akobo on 15th march, 2024.

ii. Experimental setup:

The experimental setup for the performance evaluation of a Spark Ignition Engine (SIE) using PMS and LPG consists of several key components.

The engine test bed features the TecQuipment TD200, which is a single-cylinder, four-stroke Spark Ignition Engine. It is retrofitted with a PMS/LPG dual-fuel system conversion kit (model number GX 160/200). This retrofit enables seamless switching between PMS and LPG, allowing for comparative analysis of fuel performance under identical operating conditions. The fuel supply system includes

Premium Motor Spirit (PMS) stored in a fuel tank with a calibrated flow meter to measure fuel consumption accurately. Liquefied Petroleum Gas (LPG) is supplied from a pressurized cylinder and regulated through a pressure control valve and flow meter for precise measurement. The engine test bed is equipped with a Versatile Data Acquisition System (VDAS-F) Frame Mounted, which facilitates real-time measurement and recording of engine performance parameters. It is fully capable of measuring all the essential parameters including engine speed, torque, power, fuel consumption, air intake, exhaust gas temperature, Brake Power (BP), Brake Thermal Efficiency (BTE), Volumetric Efficiency (VE), Brake Mean Effective Pressure (BMEP), Specific Fuel Consumption (SFC), and Energy Input and Output. The test procedure begins with engine preparation, ensuring the fuel supply system is properly connected, all measurement instruments were in place and calibrated, and the engine is started using PMS, allowing it to stabilize at idle speed.

For testing with PMS, the engine was run at speeds of such as 1567, 2150, 2820, 3245 and 3615 RPM. At each speed the engine parameters were recorded. The chosen engine speeds range represent a broad operating range, capturing low, medium, and high load conditions. These speeds were selected to ensure comprehensive performance evaluation without exceeding the operational limits of the test bed. For testing with LPG, the fuel system is switched, and the engine is allowed to stabilize before repeating the test cycle at the same predefined speeds. The same parameters were recorded for performance comparison.

The emission analysis was carried out using a gas analyser (model: FGA4000XDS), which was

used to measure the concentration percentages of carbon monoxide (CO), carbon dioxide (CO₂), Oxygen (O₂) and nitrogen oxides (NO, NO₂, NO_x). The exhaust probe was inserted into the engine's exhaust stream to sample the emitted gases. As the engine operates under different fuel conditions (PMS and LPG) and varying speeds, the analyser continuously records the concentration levels of the targeted emissions.

B. Sample Preparation

PMS samples were obtained from Bovas filling station, Akobo, Oyo state on 14th march, 2004 at 10:35am while LPG was obtained from Gasland gas station Akobo on 15th march, 2024. The samples were further taken to the Access oil and gas Laboratory, Ikeja, Lagos. where experiment was carried out in accordance to standards.

C. Characterisation

LPG and PMS are essential fuels used in various applications. Understanding their properties, composition, and behaviour is crucial for safe handling, efficient utilization, and environmental impact. The samples were further characterised in the laboratory in accordance with standard procedures [12]. Table 1 and Table 2 presents the Physicochemical properties, Ultimate characteristics and proximate characteristics.

i. Physicochemical properties

Physicochemical properties are the traits of a substance defined by its physical and chemical characteristics. These properties indicate how a substance behaves in different environments and conditions. The physicochemical test was carried out according to the following standards as presented in Table 1 as presented in Hasan and Rahman [13], Nguyen, et al. [6] and Iodice and Cardone [11].

Table 1: Physicochemical test

S/N	Property	Test Method (LPG)	Test Method (PMS)
1	Density	ASTM D4891	ASTM D1298
2	Boiling point	ASTM D1657	ASTM D2887
3	Vapour pressure	ASTM D6897	ASTM D5191

ii. Ultimate properties

Ultimate analysis is a laboratory procedure used to identify the elemental composition of a fuel, including carbon, hydrogen, oxygen, nitrogen, sulphur, and ash. This analysis offers a comprehensive understanding of the fuel's chemical structure, which is crucial for assessing its energy content, combustion properties, and environmental effects. The type of test and the corresponding standard to be followed are presented in Table 2.

Table 2: Ultimate analysis

S/N	Property	Test Method LPG	Test Method PMS
1	Calorific value	ASTM D2598	ASTM D5865
2	Auto ignition temperature	ASTM E659	ASTM E659
3	Flame speed	ASTM E2079	ASTM E2079
4	Research octane number (RON)	ASTM D2699	ASTM D2699
	Motor octane number (MON)	ASTM D2700	ASTM D2700

D. Performance Evaluation

The experiment was conducted using a four-stroke single-cylinder engine test bed (Tec equipment TD 200) Figure 1(a). This engine test bed is equipped with Versatile Data Acquisition System (VDAS-F) Frame-Mounted, for measuring engine Performance parameters as shown in Figure 1(a). The engine was tested

across a range of engine speeds (1000-4000 RPM) under various load conditions. Engine performance data were recorded for each fuel type, including torque, power output, fuel consumption, and exhaust gas temperature. This engine test bed was retrofitted with a PMS/LPG dual fuel system conversion kit (model number GX 160/200) as shown in Figure 1(b) with specification as shown in Table 3. The experiment evaluates specific fuel consumption and other performance metrics like volumetric efficiency, thermal efficiency, and brake mean effective pressure (BMEP) across different engine speeds.

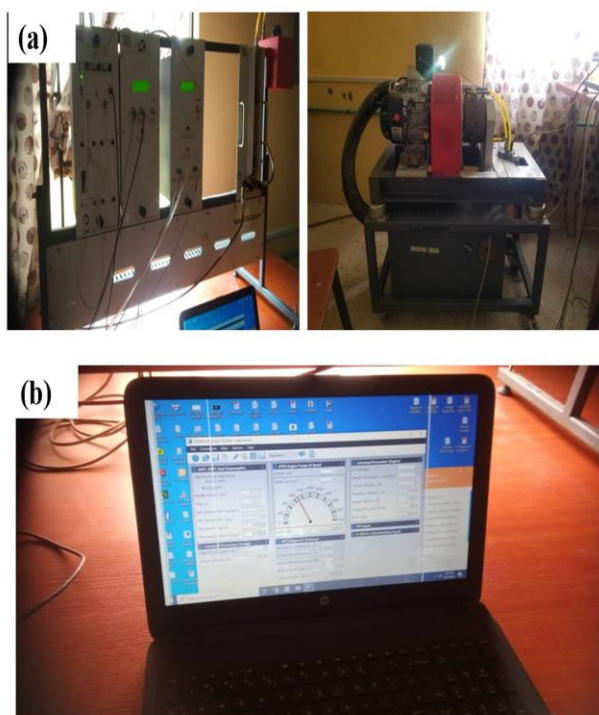


Figure1. Experimental Test Rig (a) Four Stroke Single Cylinder Engine (b) VDAS-F monitor

Table 3: Specification of LPG/PMS Conversion Kit

S/N	Parameter	Specification
1	Rated Power	4000 W
2	Maximum Output	8500 W
3	LPG Pressure Range	2.8-3.8 kPa
4	Valve Output Pressure	0.03-1.56 kPa
5	Valve Closing Pressure	3.5 kPa
6	Weight	0.88 kg

Source: Gasgen Technologies

E. Emission

The exhaust gas emitted was determined with the aid of an emission analyser which was connected to the exhaust of the engine test bed. This procedure was carried out for both PMS and LPG at various speeds and engine parameters. The gas analyser (model: FGA4000XDS) shown in Figure 2 can detect and measure the concentration percentages of various gaseous emissions, including carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂) and nitrogen oxides (NO, NO₂, NO_x).



Figure 2: Gas Analyser FGA4000XDS

III. Results and Discussion

A. The Physicochemical Properties

Physical characteristics and chemical formula s of the LPG and PMS samples were determined and result presented in Table 4. A comparative analysis of the key physicochemical properties of Premium Motor Spirit (PMS) and Liquefied Petroleum Gas (LPG) is presented in Table 5, which are crucial for evaluating their performance as fuels in SIE. The key properties

analyzed include density, viscosity, calorific value, and flash point. The LPG-fueled engine consistently demonstrated the best overall performance, particularly in terms of brake thermal efficiency and reduced specific fuel consumption. This superior performance is primarily attributed to LPG's higher-octane rating, which enhances knock resistance and promotes more complete combustion. Table 6 presents the combustion properties of PMS and LPG.

Table 4: Key Physical Characteristics and Chemical Formula of PMS and LPG

S/N	Property	PMS	LPG
1	Physical State	Volatile Liquid	Compressed Liquid
2	Appearance	Pale yellow	Colourless, transparent, and volatile liquid
3	Odour	Pungent, Sweet, and unpleasant smell	Pungent smell
4	Solubility	Insoluble in water, soluble in organic solvents	Insoluble in water, soluble in organic solvents
5	Toxicity	Toxic	Slightly toxic
6	Chemical formula Composition	C_8H_8 - Paraffins weight percentage (wt%) 55 - Naphthenes (wt%) 25 - Aromatics (wt%) 15 - Olefins (wt%) 5	Propane (C_3H_8): 60% and Butane (C_4H_{10}): 40%

B. Performance evaluation of the Spark ignition Engine at various speeds

A series of tests were performed at different engine speeds to assess key parameters, including engine torque, power output, fuel consumption, exhaust gas composition, heat of combustion, and inlet air enthalpy. In addition, performance indicators such as thermal efficiency, volumetric efficiency, and brake mean

effective pressure (BMEP) were evaluated. The findings are summarized in Table 7.

C. Emission

The emissions produced by the TD200 engine operating on Premium Motor Spirit (PMS) and Liquefied Petroleum Gas (LPG) across different engine speeds were analysed

Table 5: Comparative analysis of the physicochemical properties of PMS and LPG.

S/N	Property	PMS	LPG	Unit
1	Specific Gravity (at 15°C)	0.725	0.53	g/cm ³
2	API Gravity (at 15°C)	62.5	NA	
3	Density	0.725	0.53	g/mL
4	Viscosity (at 40°C)	0.85	NA	mm ² /s
5	Energy density	NA	46.4	
6	Flash point	45	-104	°C
7	Calorific value	10250	12500	Kcal/kg
8	Octane Rating (RON)	92	102	
9	Flash Point	45	-104	°C
10	Distillation Range (at 760 mmHg):			
	- Initial Boiling Point (IBP)	35	NA	°C
	- 10% Distillation Point	55	NA	°C
	- 50% Distillation Point	90	NA	°C
	- 90% Distillation Point	150	NA	°C
	- Final Boiling Point (FBP)	180	NA	°C

Table 6: Summary of relevant combustion properties of PMS and LPG

S/N	Property	PMS	LPG	Unit
1	Octane Rating (RON)	92	102	
2	Flash Point	45	-104	°C
3	Calorific Value	10,250	12,500	Kcal/kg
4	Sulfur Content (wt%)	0.15	0.008	%
5	Distillation Range (at 760 mmHg):			
	- Initial Boiling Point (IBP)	35	NA	°C
	- 10% Distillation Point	55	NA	°C
	- 50% Distillation Point	90	NA	°C
	- 90% Distillation Point	150	NA	°C
	- Final Boiling Point (FBP)	180	NA	°C

Table 7: Performance evaluation of the Spark ignition Engine using PMS and LPG at various speeds

Engine Speed (RPM)	Energy	Air and fuel			Efficiency					Engine		Fuel		Air and Exhaust			
		Heat of Combustion	Inlet Air Enthalpy (W)	Air Mass Flow Rate (kg/s) $\times 10^{-3}$	Fuel Mass Flow Rate (kg/s) $\times 10^{-3}$	Air/Fuel Ratio	Specific Fuel Consumption (kg/kWh)	Fuel Thermal Efficiency (%)	Volumetric Efficiency (%)	BMEP (bar)	Engine Torque (Nm)	Engine Power (W)	Fuel Volume	Fuel Drain Time (s)	Ambient Air Temperature (°C)	Exhaust Gas Temperature (°C)	Air box Differential Pressure (Pa)
PMS																	
1567	8250		710	255	170	11.6	0.348	22	73	6.50	-11.0	1807	8	37.50	21.7	520	-90
2150	12500		900	350	290	11.3	0.342	24	74	7.00	-12.5	2812	16	48.00	21.3	578	-180
2820	17500		1300	425	400	11.0	0.340	25	75	7.70	-13.5	3984	24	45.00	21.0	618	-300
3245	20800		1480	490	470	10.3	0.360	22	74	7.90	-13.8	4413	24	37.00	21.0	645	-390
3615	23500		1600	520	510	10.2	0.355	23	75	8.00	-14.2	4750	24	36.00	20.8	670	-420
LPG	8100						720	24.5	71.2	6.35	10.4	1250			21.6	485	-70
	11500						840	25.5	72.5	7.00	15.0	1750			22.1	545	-85
	15500						990	27.0	74.2	7.75	18.5	2450			21.7	615	-140
	18500						1140	26.0	75.3	8.05	21.0	2850			21.3	635	-190
	22500						1320	26.2	76.0	8.25	23.3	3450			21.0	665	-220

This evaluation provides valuable insights into combustion characteristics and emission levels, including carbon monoxide (CO), nitrogen oxides (NO_x), oxygen (O₂), and carbon dioxide (CO₂). The results of the emission analysis are presented in Tables 8.

Based on the results obtained in this research, the best outcomes can be identified based on specific criteria such as fuel efficiency, emissions, engine performance, and environmental impact. For fuel efficiency, LPG emerges as the best option, demonstrating higher thermal and volumetric efficiencies compared to PMS. This is supported by Liang, et al. [12] and Chen, et al. [14] which attribute LPG's superior efficiency to its higher-octane rating (90–110). The higher rating enables better anti-knock performance, optimized ignition timing, and more complete combustion.

In terms of emissions, LPG also proves to be the best fuel, producing significantly lower levels of carbon monoxide (CO), nitrogen oxides (NO_x) and carbon dioxide (CO₂), than PMS.

Studies indicate that LPG's lower carbon content and cleaner combustion process make it an environmentally friendly alternative. For engine power and torque, PMS shows a slight advantage over LPG. Its higher energy density releases more energy per unit of fuel, translating to increased power and torque output. However, this advantage comes at the cost of higher emissions and lower thermal efficiency. Economically and environmentally, LPG is the best choice due to its cost-effectiveness over time, reduced engine deposits, and compliance with stricter emission regulations.

Table 6: Emission using PMS and LPG as fuel at various speed

Speed	S/N	Experiment	Gas	Readings (PMS)	Readings (LPG)	Units
1567 RPM	i.	CO Emissions	CO	450	400	Ppm
	ii.	NO _x Emissions	NO _x	250	125	Ppm
	iii.	O ₂ Concentration	O ₂	1.5	1.7	%
	iv.	CO ₂ Concentration	CO ₂	11.0	8.5	%
2150 RPM	i.	CO Emissions	CO	250	250	Ppm
	ii.	NO _x Emissions	NO _x	450	110	Ppm
	iii.	O ₂ Concentration	O ₂	2.5	1.2	%
	iv.	CO ₂ Concentration	CO ₂	12.0	7.0	%
3615 RPM	i.	CO Emissions	CO	850	45	Ppm
	ii.	NO _x Emissions	NO _x	600	85	Ppm
	iii.	O ₂ Concentration	O ₂	3.5	1.3	%
	iv.	CO ₂ Concentration	CO ₂	13.0	4.7	%

IV. Conclusion

The comparative analysis of PMS and LPG in a Spark Ignition Engine reveals that while PMS delivers slightly higher power at lower speeds, LPG offers superior thermal efficiency, fuel economy, and emissions performance. These findings suggest that LPG is a viable alternative to PMS for enhancing engine efficiency and reducing environmental impact. Further research into the long-term durability of engines using LPG is recommended to fully assess its potential as a mainstream automotive fuel. Retrofitting existing engines is a viable alternative for adopting LPG as a fuel replacement for PMS. This approach is both cost-effective and practical, allowing current spark ignition (SI) engines to operate efficiently on LPG without requiring entirely new engine designs. It enables existing engines to operate on both PMS and LPG, providing flexibility to switch between fuels based on availability.

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