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Investigations on S.I. Engine Using Liquefied Petroleum Gas (LPG) As an Alternative Fuel

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Abstract:
gaseous fuels such as liquefied petroleum gas (LPG) and liquefied natural gas (LNG) have been widely used in commercial vehicles. This project evaluated an experimental investigation on Liquefied Petroleum Gas (LPG) as an alternative fuel for four-stroke spark ignition engine. The primary objective of the study was to determine the performance and the exhaust emissions of the engine using different fuels. The engine used in the study was originally a single cylinder, four-stroke spark ignition engine and minor modifications were carried out to permit the experiments to run on LPG fuel. During the running, the engine was coupled to a ropeway dynamometer to measure several engine performance parameters and a 5-gas analyzer with non dispersive infra-red (NDIR) was inserted into the engine exhaust tailpipe for measuring the exhaust emissions.

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) at various compression ratios (4.67:1,5.49:1).The engine performance studies were conducted with engine setup. Parameters like brake power, brake fuel consumption and brake thermal efficiency were calculated. The test result indicated that LPG fuel have closer performance to Gasoline fuel. However, the brake specific energy consumption shows an improvement with LPG as a fuel replacement. The concentration levels of CO, CO2 and unburnt HC recorded are found to be lower than the gasoline fueled engine.

Keywords-Liquified petroleum gas, ropeway dynamometer, NDIR, spark-ignition engine, performance, emission characteristics and electronic weighing machine.

I. INTRODUCTION

LPG is obtained from the process is the process of natural gas and crude oil extraction and as by-product of oil refining. It's primary composition is a mixture of propane and butane. It has higher octane number (105) than petrol (91-97).The use of LPG in internal combustion engines yielded higher thermal efficiency and better fuel economy compared to unleaded gasoline. This is due to mainly the higher octane rating which permits greater engine compression ratio without the occurrence of knock.LPG also has higher heating value compared to other fuels and can be liquefied in a low pressure range of 0.7 to 0.8MPa at atmospheric pressure.

Gaseous fuels such as liquefied petroleum gas (LPG) and liquefied natural gas (LNG) have been widely used in commercial vehicles, and promising results were obtained in terms of fuel economy and exhaust emissions. LPG gas as a low carbon and high octane number fuel produces lower carbon dioxide (Co_2) emission as compared to gasoline.

The use of LPG as an alternate fuel for road vehicles has been studied extensively in recent years i.e., approximately 4 million vehicles are operating on LPG worldwide. Most of these were mainly light, medium and heavy-duty trucks originally operated on gasoline and later converted to LPG using approved and certified conversion kits.

Many investigations have reported favorable results from emission perspectives when LPG is used as an alternative fuel in spark ignition engines. Emissions from LPG vehicles are significantly lower than conventionally fueled vehicles. LPG operated vehicle reported hydrocarbon (HC) emissions as 40% lower, carbon monoxide (CO) as 60% lower and carbon dioxide(co_2) as substantially reduced. In addition, since LPG has lower carbon content than gasoline, it virtually produces zero emissions of particulate matter and lower amount of NO_x emission as well.

II. EXPERIMENTAL SET-UP AND TEST PROCEDURE

A. Experimental Setup

The four-stroke spark ignition engine used in this study has a displacement of 256.56cc and a compression ratio of 4.67:1. It is a single cylinder, naturally aspirated, forced air cooled with a bowl in piston combustion chamber and equipped with a single overhead camshaft (SOHC). The detail specifications of the engine are listed in Table 2. The test rig used in this work mainly consists of the engine, a ropeway dynamometer and a non-dispersive infra red (NDIR) 5-gas analyzer. The test engine was mounted onto a steel structure, which was fabricated in the authors' machine workshop to facilitate the installation of the dynamometer. The height of the steel structure was meticulously calculated and designed to ensure perfect alignment with the dynamometer during installation. Throughout experimental testing, the whole engine and steel structure were placed on top of four-rubber damper-legs to alleviate the constant occurrence of vibration. The engine was coupled to a ropeway dynamometer using a connector. The performance of the engine running on both gasoline and LPG were basically determined from data obtained from the dynamometer. The ropeway dynamometer permits different load measurement in this study. A NDIR 5-gas analyzer was positioned at the exhaust tailpipe for emission measurement. The analyzer has the capability of sampling various exhaust products such as hydrocarbon (HC), carbon monoxide (CO), and carbon dioxide (CO2) with the option of oxygen (O2) and oxides of nitrogen (NOx). All exhaust gases were sampled at a point of around 15cm beyond the exhaust valve.

TABLE 1. Comparison of LPG and Gasoline properties

Characteristics	**LPG**	**Gasoline**
Chemical formula	C_3H_8	C_8H_{18}
Boiling point (^{0}C)	-44	30-225
Molecular weight (kg/Kmol)	44.1	114.2
Density at 15 ^{0}C (kg/l)	0.53	0.7372
Research Octane Number	100	96-98
Stoichiometric air fuel ratio (kg/kg)	15.6	14.7
Flame speed (m/s)	48	52-58
Upper Flammability limits in air (% vol.)	74.5	7.6
Lower Flammability limits in air (% vol.)	4.1	1.3
Calorific value (kJ/kg)	46100	43000

B. Test Procedures

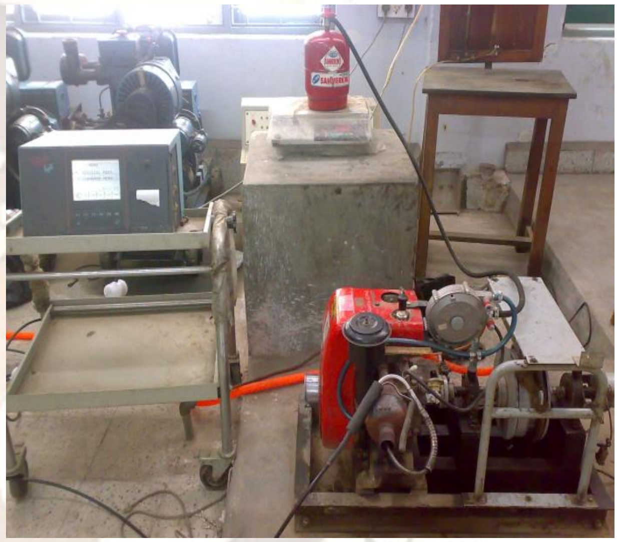


Figure 1. Fabricated the experimental set-up

TABLE 2. Specifications of the engine

Type	1cy.& 4str. S.I. Engine
Make/model	Greaves / MK-25
Rated power	2.2kw
Speed	3000 r.p.m.
Bore & stroke (mm)	70 x 66.7
Cubic capacity (cc)	256.56 cc
Compression ratio	4.67 : 1
Rope drum radius (r)	10.4 cm
Length of the arm (l)	36.2 cm
s.f.c. (g/kwh)	0.5

Radius of shaft (r)	2.8 cm

Following the experimental methodology can be used:

- ❖ The LPG kit, pressure valve and regulator are assembled with each other as per the shown in the experimental set up.
- ❖ "ON" the LPG cylinder regulator.
- ❖ Before start the engine ensure any leakages in the set up.
- ❖ LPG supply to the engine is controlled by a regulator or vaporizer. This converts the LPG into a vapour.
- ❖ The vapour is fed into a mixer located near the intake manifold. Where it is mixed with filtered air before being drawn into the combustion chamber.
- ❖ When we apply load on rope dynamometer it will get heated up. So we will continually supply coolant water.
- ❖ At different load conditions we will take shaft speed in RPM with the help of tachometer, using different fuels .i.e. Gasoline, LPG.
- ❖ Time collection of 30cubic capacity of fuel consumption for Gasoline and 16g LPG consumption using at different load condition
- ❖ From the results we will calculate Torque (T), Brake power (BP) and Break Thermal Efficiency (η_{bth}).

III. RESULTS AND DISCUSSION

A. Observation Tables

Observation table for using Gasoline fuel at CR 4.67:1

load(m) (Kg)	speed(N) (r.p.m.)	time (t) (sec)
no load	2941	159.72
1.5	2910	155.2
2.5	2875	149.82
3.5	2840	142.28
4.5	2786	138.53
5.5	2725	134.09

Observation table for Using LPG fuel at CR 4.67:1

load(m) (Kg)	speed(N) (r.p.m.)	time (t) (sec)
no load	2941	115.64
1.5	2910	108.06
2.5	2875	103.21
3.5	2840	96.92
4.5	2786	91.45

After changing the compression ratio from 4.67 to 5.49 the observation tables for using with Gasoline and LPG we will get another two observation tables by applying same loads.

B. Engine Performance

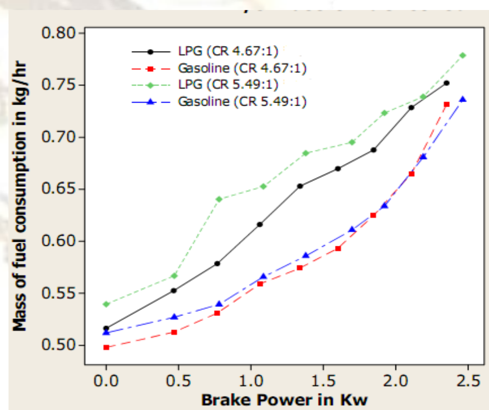
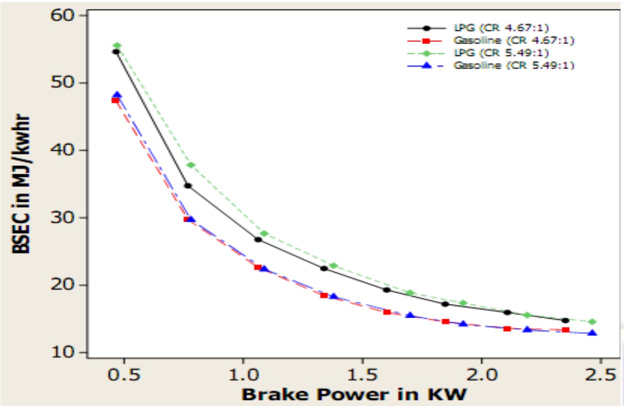


Figure: Brake Power v/s Mass of fuel consumption

Above Figure indicate that the mass of fuel consumption gradually increasing w.r.t. increasing the Brake Power. The maximum mass of fuel consumption with LPG is 0.7523 kg/hr at 2.350 KW (CR 4.67:1); 0.7787 kg/hr at 2.463 KW (CR 5.49:1), and maximum mass of fuel consumption with petrol is 0.7313 kg/hr at 2.350 KW (CR 4.67:1); 0.7360 kg/hr at 2.463 KW (CR 5.49:1).

As can be clearly seen from this figure, LPG increases mass of fuel consumption of the engine in comparison with petrol .Using Gasoline fuel the mass of fuel consumption values slightly lower than the using LPG-fuel.



Above figure indicate that the brake specific energy consumption decreases as the load on the engine increases. The minimum BSEC with LPG is 14.752 MJ/kwhr at 2.350 (CR 4.69:1); 14.570 MJ/kwhr at 2.463KW (CR 5.49:1); and minimum brake specific fuel consumption with petrol is 13.373 MJ/kwhr at 2.350 KW (CR 4.67:1); 12.840 MJ/kwhr at 2.463 KW (CR 5.49:1). As can be clearly seen from this figure, LPG increases the specific fuel consumption of the engine in comparison with petrol.

This graph shows BSEC of Gasoline and LPG values are gradually decreasing w.r.t. increasing the Brake Power. 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).

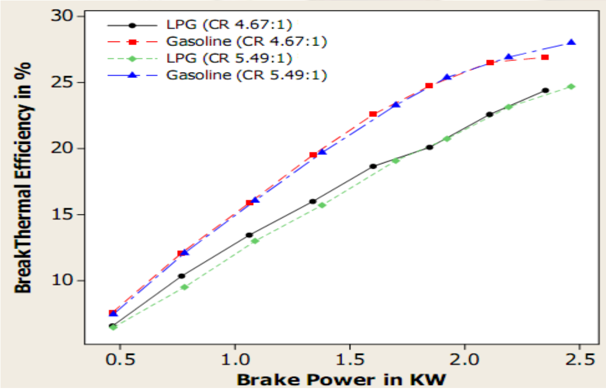


Figure: Brake Power v/s Brake Thermal Efficiency

From Figure it is found that, as the brake power increases, there is considerable amount of increase in brake thermal efficiency. The maximum brake thermal efficiency with petrol is 26.91% at BP 2.350 KW (CR 4.69:1); 28.01% at BP 2.46 KW (CR 5.49:1); and maximum brake thermal efficiency with LPG is 24.40% at BP 2.350 KW (CR 4.69:1); 24.69% at BP 2.463 KW (CR 5.49:1)

Above graph shows brake thermal Efficiency of the engine is gradually increasing w.r.t. increasing the Power. However, the Brake Thermal efficiency increases when the compression ratio increases. When using Gasoline fuel the Efficiency values slightly higher than the using LPG fuel.

C. Emission Characteristics

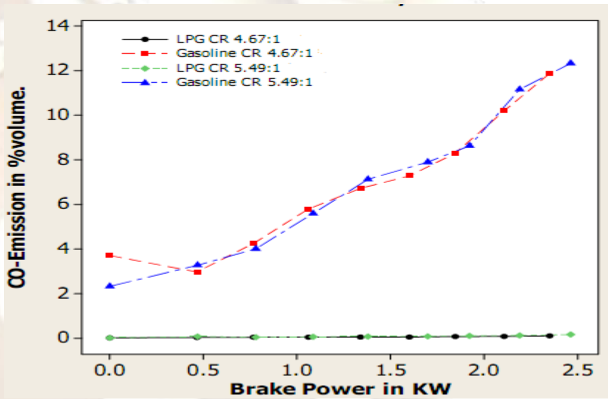


Figure: Brake Power v/s CO-Emission

CO is produced when there is not enough air in the combustion chamber. When the fuel does not burn completely; the carbon in the fuel will convert into CO. It was found that there was a variation trend of CO for the LPG fuel system when it is operated at normal and high operating conditions. As it is seen in the compression ratio increases, speed and CO emissions also increase.

The maximum value of CO emissions for LPG are 0.11% at BP 2.350 KW, (CR 4.67:1); 0.17% at BP 2.46 KW (CR 5.49:1); and the maximum value of CO emissions for petrol are 11.88% at 2.350 KW (CR 4.67:1); 12.33% at BP 2.46 KW (CR5.49:1); The CO emission increases with incomplete combustion of fuel and it is higher with petrol compared with LPG.

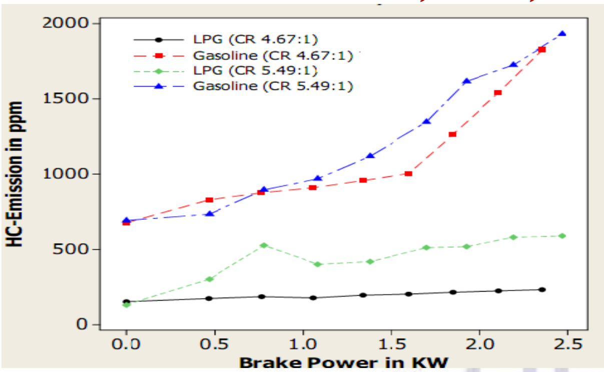
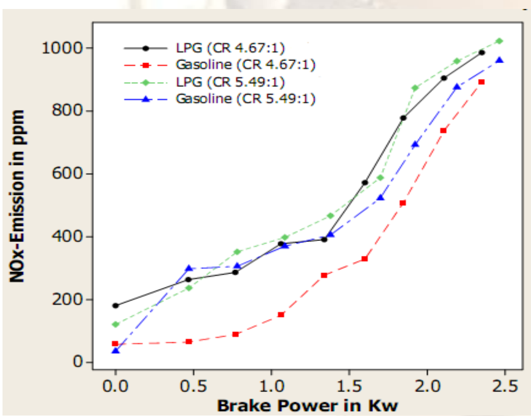
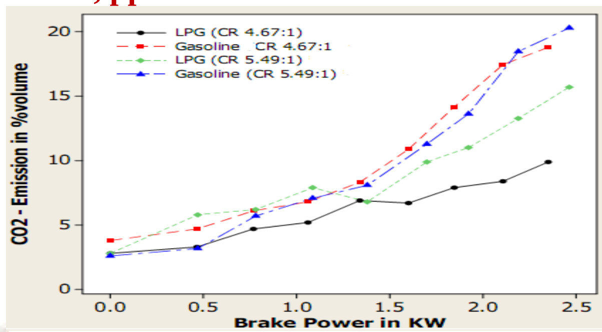


Figure: Brake Power v/s HC-Emission

From it is found that as the compression ratio increases, speed and HC emission increase. Maximum HC emission for LPG is 230 ppm at BP 2.350 KW, CR 4.67:1; 259 ppm at BP 2.46 KW (CR 5.49:1); and with petrol, 1829 ppm at 2.350 KW, CR 4.67:1; 1930 ppm at BP 2.46 KW, CR 5.49:1. CO emission increases with incomplete combustion of fuel and it is higher for petrol when compared with LPG.



From Figure it is found that as the NO_x emission increase w.r.t Brake Power increases. Maximum NOx emission for LPG is 986 ppm at BP 2.350 KW, CR 4.67:1; 1023 ppm at BP 2.46 KW (CR 5.49:1); and with petrol 893 particles per minute (ppm) at 2.350 KW, CR 4.67:1; 961 ppm at BP 2.46 KW, CR 5.49:1. and NO_x is higher for LPG when compared with Gasoline.



From the above figure it is found that as the compression ratio increases, Brake Power and HC emission increase. Maximum CO_2 emission for LPG is 9.9% at BP 2.350 KW, CR 4.67:1; 15.7% at BP 2.46 KW (CR 5.49:1); and with petrol, 18.8% at 2.350 KW, CR 4.67:1; 20.3% at BP 2.46 KW, CR 5.49:1. CO_2 emission increases with incomplete combustion of fuel and it is higher for petrol when compared with LPG.

IV.CONCLUSION

As compression ratio increases, brake thermal efficiency increases. LPG has a higher octane rating and hence the engine can run effectively at relatively high compression ratios without knock. The 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. Combustion of gaseous fuels like LPG occurs in a nearly uniform fuel air mixture leading to a reduction in incomplete combustion deposits such as soot on the walls of combustion chamber. 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.

V. FUTURESCOPE

The above set up is presently studied under the using Liquefied Petroleum Gas (LPG) at variable compression ratios on the single cylinder four stroke spark-ignition engine, but the same set up can be studied for compare Gasoline and LPG – Gasoline blends (25%, 50%, 75% of LPG in Gasoline.) at various compression ratios of the engine. Then found engine performance parameters like BSFC, BSEC, Mf, Brake Power and Brake thermal efficiency at various loads applying on the engine.

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