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# An Experimental and Emission Performance Analysis of Single Cylinder S.I. Engine Test with Electrical Loading by Using Alternative Fuels

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**ABSTRACT:** IC engines are considered as major contributors to the deterioration of the environment, therefore there is an increasing demand to go for alternative fuels for SI engine so as to maintain the ecological balance as well as reduce dependency on petroleum and socio economic aspects. The gaseous fuel such as LPG has been widely used throughout the world in SI engines as it impacts greenhouse emissions less than any other fossil fuel. Many researchers have carried out large number of studies on LPG fueled in SI engine and it was reported that the use of LPG has a significant effect on engine performance. In the studies carried out it was found that the concentration level of CO, HC and CO<sub>2</sub> were on the lower side for LPG as compared to gasoline for the same power output, but the concentration of NO<sub>x</sub> for the same power output was higher for LPG than Gasoline. SI engine fueled with LPG resulted in a decrease in power output and volumetric efficiency as compared to gasoline and the specific fuel consumption for LPG, values slightly higher than gasoline. This paper presentation a general overview about the previous research efforts into SI engine using LPG as an alternative fuel for the purpose of improving emission characteristics and engine performance.

**KEYWORDS:** Ethanol, Petrol fuel, thermal efficiency, Emissions.

### I. INTRODUCTION

Various undesirable emissions are exhausted by the internal combustion (IC) engines which affect the environment and cause various problems such as ozone depletion, acid precipitation, global warming, respiratory hazards etc. Scientific results show that the contribution to global anthropogenic emissions from transportation amount to 21% of CO<sub>2</sub>, 37% of NO<sub>x</sub>, 19% of volatile organic compounds (VOCs), 18% of CO and 14% of black carbon, the main source of carbonyls and VOCs result directly from incomplete combustion of fossil fuel such as vehicle exhausts and biomass burning. Therefore it is very important for the researchers to arrive at the clean burning fuel to contribute in reducing the environment problems and growth of global warming. In recent years in order to reduce the environmental damage of motor vehicles and meet the stringent emission regulations, clean alternative fuels such as liquefied petroleum gas (LPG), natural gas (NG) and Hydrogen (H) have been applied in the motor vehicles. Liquefied Petroleum Gas (LPG or LP gas) also referred to as simply propane or butane or a mixture of propane (C<sub>3</sub>H<sub>8</sub>) and butane (C<sub>4</sub>H<sub>10</sub>), is a flammable mixture of hydrocarbon gases used as a fuel in heating appliances, cooking equipment and vehicles. LPG is prepared by refining petroleum or wet natural gas, and is almost entirely derived from fossil fuel sources, being manufactured during the refining of petroleum (crude oil), or extracted from petroleum or natural gas streams as they emerge from the ground. LPG also contains propylene and butylenes in small concentration. A powerful odorant, ethanethiol also known as ethyl mercaptan (CH<sub>3</sub>CH<sub>2</sub>SH) is also added in a container, containing LPG so that leaks can be easily detected. LPG is widely used as an alternative fuel in automobile due to its efficient combustion characteristics and low emissions. It has a higher octane

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rating (105-112) as compared to petrol (91-97), which enables it to use at higher compression ratio and thus improves thermal efficiency of engine. Further due to high octane number it prevents the occurrence of knock.

It's higher heating value, octane number, auto ignition temperature and wider flammability limits makes LPG a better SI engine fuel than gasoline. LPG is a gas at atmospheric pressure and normal temperatures, but it can be liquefied when moderate pressure (0.7 to 0.8 MPa) is applied or when the temperature is sufficiently reduced. This property makes LPG an ideal energy source for a wide range of applications, as it can be easily condensed, packaged, stored and utilised. When the pressure is released, the liquid makes up about 270 times its volume as gas, so large amounts of energy can be stored and transported compactly. LPG has been suggested as a convenient clean burning less pollutant fuel, therefore it is also known as Green Fuel. Since LPG burns cleaner with less carbon build up, oil contamination, engine wear is reduced and life of some components such as piston rings and bearing are much higher than with gasoline.

It has been reported that the use of LPG yields 40% less HC, 35% less Nox, 50% less CO and 50% less ozone forming potential as compared to gasoline. LPG is also free of particulates, the main pollutant of diesel and GDI engines. The US department of energy reported that LPG not only has lower green house emissions than petrol and CNG but also it surpasses a number of highly promoted bio-fuels, fig. 1 below shows the level of Greenhouse gases of various fuels.

The use of LPG as an alternative fuel for gasoline has been studied extensively in recent years. This represents an detailed theoretical investigation on the performance and emission characteristics of SI engine fueled with LPG at different operating parameters and operating conditions.

## II. WORKING PRINCIPLE OF FOUR STROKE S.I ENGINE :

A mixture of fuel with correct amount of air is exploded in an engine cylinder which is closed at one end. As a result of this explosion, heat is released and this heat causes the pressure of the burning gases to increase. This pressure forces a close fitting piston to move down the cylinder. The movement of piston is transmitted to a crankshaft by a connecting rod so that the crankshaft rotates and turns a flywheel connected to it. Power is taken from the rotating crank shaft to do mechanical work. To obtain continuous rotation of the crankshaft the explosion has to be repeated continuously.

### A) FOUR STROKE CYCLE FOR SI ENGINE:

In four stroke cycle engines the four events namely suction, compression, power and exhaust take place inside the engine cylinder. The four events are completed in four strokes of the piston (two revolutions of the crank shaft). This engine has got valves for controlling the inlet of charge and outlet of exhaust gases. The opening and closing of the valve is controlled by cams, fitted on camshaft. The camshaft is driven by crankshaft with the help of suitable gears or chains. The camshaft runs at half the speed of the crankshaft. The events taking place in I.C. engine are as follows:

1. Suction stroke
2. Compression stroke
3. Power stroke
4. Exhaust stroke

### B) EXPERIMENTAL SETUP:

The KUBOTA engine-generator set (AE2400LX) used for test purpose consisted of a - 200cc, single cylinder, 4-stroke, air-cooled SI engine directly coupled with a generator of rated output capacity of 1.5 kW, 220V, 50Hz electricity. As the final electric output is the main concern of the engine-generator set, electric loading was used instead of a conventional dynamometer. A number of incandescent lamps mounted parallel on a panel board, was used as variable electric loads. Although the engine was designed for running on petrol, it was adopted to run on supply of liquified petroleum gas during part of this study. It was desired to run the engine on LPG with minimum modification to the hardware and retaining the capability of switching back to its petrol fueling system easily. For this simple modification in the air intake structure incorporating an external mixing chamber was designed. The mixing chamber

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used for test purpose was of cross flow type where part of the original air intake of the engine was replaced by a modified one. Petrol and LPG flow were measured volumetrically, using burette and flow meter respectively. The air flow rate was measured by allowing the air to pass through an air drum mounted with a small parabolic nozzle at its entrance and taking the vacuum pressure reading of the nozzle exit point with an inclined manometer. The LPG used in testing was obtained from commercially available LPG cylinder (Bashundhara, 12.5 kg, 120 psi). The supply cylinder was fitted with a regulator valve. To reduce the outlet pressure to just above atmospheric, additional fluid impedance (brass plug of 1/8 inch hole, 0.5 inch outer dia and 1.5 inch length) was added on the line. Exhaust gas was analyzed using a 4-gas emission analyzer (CRYPTON 290). The percentage of oxygen (O<sub>2</sub>), carbon-di-oxide, (CO<sub>2</sub>) and carbon-monoxide (CO), total hydrocarbon (HC) in ppm, equivalent ratio of the intake air-fuel mixture and the engine speed was measured using the analyzer for both the fuels.

## 1. 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 30 cubic 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 ( $\eta_{bth}$ ).

## C) PERFORMANCE OF THE ENGINE RUNNING ON PETROL AND LPG:

The study of performance with petrol fuel provides valuable base data indicating the designed performance of the engine-generator set. The performance while running on LP gas can be compared with this. The variation of air flow rate, fuel flow rate, air-fuel ratio, brake specific fuel consumption, overall efficiency, percentage of exhaust emission components, engine speed, voltage generated, current drawn and temperature of the engine with electrical load- were the main parameters studied in the case of the petrol as well as the LP gas. The test were carried out with variable electric loads up to the rated value (1.5 KW). Air Flow Rate shows the comparison of variation of air flow rate with increasing load for both the fuels. While running with petrol, the air-flow rate of the engine increased gradually. At no-load condition the airflow rate was found to be around 5.4 kg/h and was raised to around 11 kg/h at its rated full load. While running with the LP gas, the air-flow rate was found to be about 4.8 kg/h at no load and it was raised to about 9.8 kg/h at full load condition. With LPG the airflow rate was found to be about 85-90% of that of petrol. This is caused by the relatively greater volume occupied by the LP gas in the air-fuel mixture, fed into the intake manifold of an engine running at fixed speed. Fuel Flow Rate shows the variation of the fuel flow rate with increasing load for both the fuels. For both cases mass flow rate data was calculated from the volumetric measurement. But there was a variation between the two curves. For petrol, the fuel consumption was higher. At no load condition petrol flow was about 0.52 kg/h and in full load the value was about 1 kg/h. For LPG the engine was running on a relatively constant flow as there was little variation of LP gas flow with change of throttle position. The flow rate of fuel was controlled manually with a precision regulating valve, for a number of different loading ranges. From zero load to 400 watt the fuel flow was about 0.50 kg/h. From 400 to 800 Watts this was about 0.55 kg/h, and about 0.62 kg/h up to 1200 Watts. The maximum load taken by the engine-generator running on LPG was about 1.3 kW with a flow rate of about 0.78 kg/h.

It should be noted that Petrol has a stoichiometric ratio of about 14.8 while the LPG has 15.6. In addition calculated values from air and fuel flow rates, the exhaust gas analyzer also provided an equivalence ratio and air-fuel ratio data, by analyzing the product of combustion. This gave a useful way for counter checking the measured values. Compares the air-fuel ratio results found by calculation and measurements from the analyzer for both the fuels the calculated values using measurements for air and fuel flow rate show good agreement with the readings from the exhaust gas analyzer, other than low power range (with small throttle opening). Variation of the air-fuel ratios with

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different loads were also found to be in a limited range, specially with petrol 10-12 and 10-13.5 for LPG. Engine Speed The engine speed was measured using the inductive rpm probe with the analyzer. This works by counting the number of sparks that pass through the spark plug. Both petrol and LP gas shows similar behavior in variation of engine speed.. At no load condition the speed for petrol was 1503 rpm whereas the speed for LPG was 1485 rpm. The speed decreases with increase in load in the both cases. At full load the speed was 1460 for petrol and 1410 for LPG. Figure-6 and 7 show the variation of engine speed and voltage generated by the system respectively for both fuels.

## 1. Bsf and Overall Efficiency:

For both fuels brake specific fuel consumption rates were very high at lower loads and decreased gradually at higher load region, as shown in figure-8. For petrol this value was around 1900 g/kw-h at 380W load and was found to be about 625 g/kw-h at the rated load. For LP gas Bsf was found to be 1650 g/kw-h at 400W load and it decreased gradually to 620 g/kw-h at 1.32 kW, which was the maximum load achieved. Different Bsf values do not necessarily indicate comparative performance with different fuels, as they might have different heating values. This can be studied using the equivalent Bsf or comparing their thermal/overall efficiencies. Since the final electric power output is the desired parameter, the overall efficiencies were compared. shows the variation overall efficiencies for the engine running on both the fuels. In both cases efficiency improve at higher loads, while the operation with LPG (up to 13.5%) exceeds the performance with petrol (12%). This apparent improvement in overall efficiency has more to do with the improper or incomplete combustion of petrol, rather than real enhancement of the efficiency using LP gas. The higher airflow rate for petrol indicates that improper mixing rather than lack of air, most probably is the main cause of its higher fuel consumption rate.

## 2. Emission Analysis:

The variation of emission gas components with petrol. CO, CO<sub>2</sub> and unburned O<sub>2</sub> is expressed in percentage volumes while the total unburned hydro-carbon is given as parts per million (ppm). The amount of CO varies between 6-10% with increased load for petrol, which is about 6-8% for LPG. At the same time the amount of CO<sub>2</sub> varies between 5-9% with increased load for petrol, which is about 6-10% for LPG. The amount of HC varied between 1200-600 ppm for petrol and between 1100-500 for LPG along the load range.

## 3. Temperature:

For both fuels the engine body and lubricating oil temperatures increased slightly with load. The engine body temperature was varied from 50°C to 68°C for both fuels for full load condition. The variation of lub-oil temperature (84°C-107°C) was slightly higher for LPG at low loads compared to petrol (70°C-107°C). The exhaust gas temperature for petrol ranging from 80°C-160°C and 115°C-198°C for LPG. The variation of lubricating oil temperature and engine body temperature (only about 100°C) was noted with LP gas, although the exhaust temperature was 20% higher. This was promising, indicating less possibility of variation in expected longevity of engine parts, when using LPG.

## 4. Emission characteristics:

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 (CR 5.49:1); The CO emission increases with incomplete combustion of fuel and it is higher with petrol compared with LPG.

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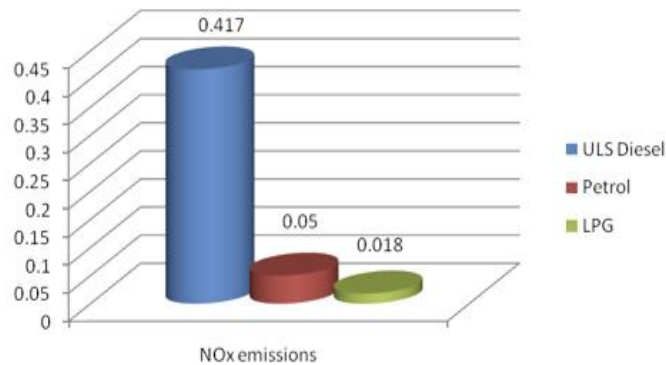
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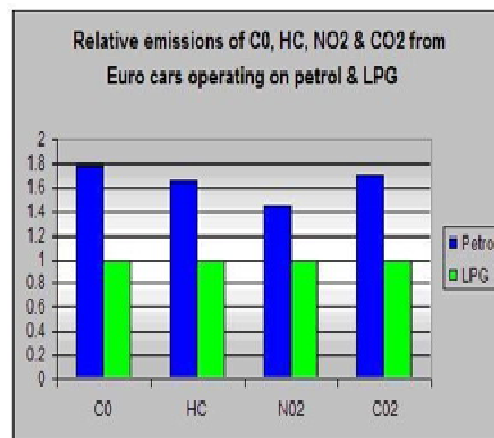
## TABULATION

		Petrol	Diesel	LPG	Rel. LPG-petrol %	Rel. Diesel-LPG %
NH <sub>3</sub>	[mg/km]	17.3	0.9	50.6	292	2
SO <sub>2</sub>	[mg/km]	8.9	3.7	2.8	31	132
N <sub>2</sub> O	[mg/km]	3	7	3	100	233
NO	[g/km]	0.07	0.33	0.05	71	660
NO <sub>2</sub>	[g/km]	0.02	0.37	0.01	50	3700
OC	[mg/km]	1.1	11.5	0.4	37	2875
EC	[mg/km]	0.6	26.1	0.2	33	13050
CO	[g/km]	1.48	0.10	1.39	94	7
HC	[g/km]	0.13	0.02	0.10	77	20
NO <sub>x</sub>	[g/km]	0.10	0.80	0.07	70	1143
HC+NO <sub>x</sub>	[g/km]	0.24	0.83	0.18	75	461
PM	[g/km]	0.006	0.046	0.005	83	920
CO <sub>2</sub>	[g/km]	208.1	180.5	189.3	91	95
FC	[l/100km]	8.86	6.78	11.74	-	-

GRAPH:1



GRAPH:2



## III. ADVANTAGES

- You will be driving in a more environmental-friendly way, the gain from the use of Auto gas for vehicles are undeniable.
- Engine noise is reduced.



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- LPG is better than petrol because it reaches the engine in gas form leading to improved combustion.
- The life of the engine is increased because of the absence of the acid and carbon deposits.
- Exhaust emissions contain less harmful substances when compared to petrol and diesel.

## IV. FUTURE SCOPE

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.

## V. CONCLUSIONS

The small-scale power generator driving SI engine could be run on LPG with simple modification at the air intake system of the engine, while keeping the rest of the system intact. This can be very useful and cost effective way of running the engine on LPG, while retaining the instant inter-change ability of the system back to petrol fuel. It was easier to start the engine with petrol and then switching over to the LPG fuelling system. While running on LPG, the gas flow rate needed to be regulated for smooth engine operation with varying load. The SI engines with of small capacity were found to be not very energy efficient devices for power generation, causing relatively high level of environmental pollution. Relatively poor mixing of fuel with air in the small engine seemed to be the main reason of poor combustion leading to higher fuel consumption and greater environmental pollution. Therefore it is inconvenient to use small capacity generator in congested places from both energy efficiency and environmental safety point of view. Using LPG in the engine resulted in better mixing and combustion, lower fuel consumption and improved emission characteristics.

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