Performance Testing of SI Engine using LPG as Alternate Fuel

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ABSTRACT

With the advent of time an increased exhort to make environment sustainable has been a driving force for many researchers. There has been a lot of pragmatic work captured under various initiatives and schemes where the thrust has always been upon securing a cleaner emission. In order to strive for cleaner emissions with higher efficiency, experimentation has delivered positive results. Transcending from petrol and diesel, the inclination is more on leading to fuels which are not only efficient like the conventional ones but at the same time will yield lesser harmful elements post combustion in engines. Application of alternate fuels like Liquid Petroleum Gas (LPG) and Compressed Natural Gas (CNG) are gaining in prominence now since they are not only less harmful but also deliver equivalent efficiency. This paper would go on to showcase an experiment that achieved a prominent result of LPG usage over petrol in a Spark Ignition (SI) engine. The application of alternate fuels would gradually increase and is expected to comprehend the usage of alternate fuels, both used in pure as well as in blend. A lot of scope lies in experimenting out various fuels with workable caloric value, which would supplement the usage of automobile in the upcoming generation.

Keywords: Alternative Fuels; Performance Characteristics; S.I. Engine Testing; LPG as fuel; Engine Efficiency
1. INTRODUCTION

In recent years, legislative and market requirements have driven the need to reduce fuel consumption while meeting increasingly stringent exhaust emissions. This trend has dictated increasing complexity in automotive engines and new approaches to engine design. A key research objective for the automotive engineering community has been the potential combination of gasoline-engine specific power with diesel-like engine efficiency in a cost-competitive, production-feasible power train.

LPG is obtained from hydrocarbons produced during refining of crude oil and from heavier components of natural gas. It is petroleum derived colourless 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. The main purpose of carrying out this experimental test was to draw a fair comparison between petrol and LPG as fuel in SI engine load testing.

2. METHODOLOGY

This experimental performance requires auxiliary instruments to support this test. Since there was an implementation of gas injection in the system, additional measures were taken to adhere to those practices. Few of the basic modifications that was done on the SI engine were:

1. Fabrication of frame for performance testing
2. Fitting of nozzle on intake manifold
3. Using of solenoid valve for flow control technique.

2.1. Fabrication of frame for performance testing

Fabrication of frame for performance testing

The frame is made for the performance testing of engine for this angle section bars were welded and engine was mounted inclined angle bars were welded for installing the spring balance and load test arrangement. The nozzle along with the solenoid operated injection setup was casted at the intake manifold. By doing this the fuel will directly open up into the intake manifold and hence will result in superior output.

The nozzle was fitted by drilling on top of the carburetor. The solenoid valve installed basically works in the flow processing. It also regulate the flow control, and it receives signals from the engine where it fluctuates its inlet and outlet valve. A gas kit comprising LPG gas cylinder, vapouriser, regulator, solenoid valve where successfully installed into the experimental process which yielded proper result. Elaboration about vapouriser, solenoid valve and regulator. Vaporiser or Converter name stand for device which convert liquid state of fuel into gas or vapour. Sometime it is called reducer also as it reduce pressure of high pressurized liquid state fuel so it convert into gas or vapour. This product is a kind of stop valve mainly used on vehicle LPG gas pipeline.
When the vehicle consumes LPG, this valve will open automatically in order to ensure that gas flow smoothly and satisfy the LPG combustion need of the vehicle and has a built-in filter to remove impurity from the LPG. A solenoid valve has two main parts: the solenoid and the valve. The solenoid converts electrical energy into mechanical energy which, in turn, opens or closes the valve mechanically. It regulates the pressure of the gas. LPG stored in the cylinder at 200 bar and in liquefied state hence solenoid helps in regulating the pressure and bringing down the at around 1.5 bar.

2. 2. Fitting of nozzle on intake manifold

The nozzle along with the solenoid operated injection setup was casted at the intake manifold. By doing this the fuel will directly open up into the intake manifold and hence will result in superior output. The nozzle was fitted by drilling on top of the carburetor.

2. 3. Using of solenoid valve for flow control technique

The solenoid valve installed basically works in the flow processing. It also regulates the flow control, and it receives signals from the engine where it fluctuates its inlet and outlet valve.

2. 4. Implementation of gas kit

A gas kit comprising LPG gas cylinder, vapouriser, regulator, solenoid valve where successfully installed into the experimental process which yielded proper result. Elaboration about vapouriser, solenoid valve and regulator.

2. 5. Vaporizer

Vaporizers or Converter name stand for device which convert liquid state of fuel into gas or vapour. Sometime it is called reducer also as it reduce pressure of high pressurized liquid state fuel so it convert into gas or vapour. Vaporizer consists of main body of metal by pressure die casting process subsequently followed by vacuum impregnation, shot blasting & hard anodizing process. For pressure drop & maintaining continuous flow requirement generally done either in 3 or 2 stages with the help of diaphragms & lever arrangement set in the main body. Quantity & quality of fuel flow is depend on port diameter of fine precision jet & the volume enclosed by diaphragms. Here jet seat machining, matching rubber pad of high quality long life material & appropriate designed diaphragms control the vaporizers performance.

2. 6. Solenoid Valve

This product is a kind of stop valve mainly used on vehicle LPG gas pipeline. When the vehicle consumes LPG, this valve will open automatically in order to ensure that gas flow smoothly and satisfy the LPG combustion need of the vehicle and has a built-in filter to remove impurity from the LPG. A solenoid valve has two main parts: the solenoid and the valve. The solenoid converts electrical energy into mechanical energy which, in turn, opens or closes the valve mechanically. A direct acting valve has only a small flow circuit. This diaphragm piloted valve multiplies this small flow by using it to control the flow through a much larger orifice.
2.7. **Pressure Regulator**

It regulates the pressure of the gas. LPG stored in the cylinder at 200 bar and in liquefied state hence solenoid helps in regulating the pressure and bringing down to around 1.5 bar.

3. **APPARATUS USED FOR PERFORMANCE TESTING**

1. Burette: - It is used for measuring the fuel supply.
2. Thermometer: - Thermometer (0-300 °C) is used for measuring for exhaust gas temperature.
3. Stopwatch: - It is used fuel flow rate.
4. Spring balance: - It is used for calculating load on engine.
5. Weight pan weights: - Weights are kept on the on the weight pan to different load. The weight pan is suspended on the rope.
6. Battery: - It is used to drive the motor.
7. Tachometer: - It is used measure the rpm of the drum
8. Digital weight machine: It is used to measure the weight of cylinder which helps in finding out the LPG weight

4. **PROCEDURE OF TESTING ON CONVENTIONAL SYSTEM**

1. Engine started and the speed is maintained at constant rpm.
2. Time required for the flow 20cc petrol is measured.
3. Add weight on the weight pan and measure the spring balance reading.
4. The various rpm’s put to test were 200, 300 and 400.
5. The loads that were subjected for the testing were 4, 6 and 6.5 kgs.
6. Similar readings on same parameters were calculated in LPG as well
7. Repeat the above procedure for concurrent readings.
8. In case of LPG testing of cylinder weight is done by using digital weight balance.

**Difficulties Faced**

1. Faced the problem of selecting appropriate type of engine, which has separate lubricating system and in good working condition.
2. Another problem was while taking conventional testing where the test rig erupted problem.
3. Difficulties fixing the nozzle injection system on to the cylinder head.
4. The irregularity of the flow of petrol and intermittent supply of gas was prominent.

**Limitations**

1. Inability to make direct injection system, hence we concluded in making a port injection system.
2. The unavailability of adequate processes including that of ECM synchronization was severely felt.
Engine specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement</td>
<td>92.2cc</td>
</tr>
<tr>
<td>Bore*Stroke</td>
<td>50 mm*56.9 mm</td>
</tr>
<tr>
<td>Power</td>
<td>7.4bhp (5.4kw)</td>
</tr>
<tr>
<td>Torque</td>
<td>7.85Nm</td>
</tr>
<tr>
<td>Engine type</td>
<td>Bajaj</td>
</tr>
<tr>
<td>Cooling system</td>
<td>Air cooled</td>
</tr>
<tr>
<td>Rpm</td>
<td>5800</td>
</tr>
<tr>
<td>Stroke</td>
<td>4T</td>
</tr>
<tr>
<td>No of cylinder</td>
<td>Single</td>
</tr>
</tbody>
</table>

Dynamometer:
Rope brake dynamometer
Diameter of rope = 0.45cm
Diameter of drum = 23.3cm

5. OBSERVATION TABLE

The following observation table gives us a detailed result and readings that were taken during the testing. Now as it can be seen that readings at different rpm’s like that of 200, 300 and 400 are taken at loads like 4 and 6 Kgs

Table 1. Observation table for Petrol.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>RPM</th>
<th>Load (w-s) (KG)</th>
<th>Manometric reading (Cm)</th>
<th>Time for 20cc fuel consumption (sec)</th>
<th>mf*10^-4 (kg/sec)</th>
<th>BP (KW)</th>
<th>BSFC (Kg/kw hr)</th>
<th>ma/mf</th>
<th>Thermal efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>200</td>
<td>4</td>
<td>2</td>
<td>178</td>
<td>0.842</td>
<td>0.1038</td>
<td>2.92</td>
<td>23.343</td>
<td>2.86</td>
</tr>
<tr>
<td>2.</td>
<td>200</td>
<td>6</td>
<td>3</td>
<td>112</td>
<td>1.33</td>
<td>0.156</td>
<td>3.06</td>
<td>17.231</td>
<td>2.72</td>
</tr>
<tr>
<td>3.</td>
<td>300</td>
<td>4</td>
<td>2.7</td>
<td>228</td>
<td>0.657</td>
<td>0.156</td>
<td>1.51</td>
<td>12.936</td>
<td>5.52</td>
</tr>
<tr>
<td>4.</td>
<td>300</td>
<td>6</td>
<td>5.7</td>
<td>136</td>
<td>1.10</td>
<td>0.234</td>
<td>1.69</td>
<td>20.162</td>
<td>4.94</td>
</tr>
<tr>
<td>5.</td>
<td>400</td>
<td>4</td>
<td>6.5</td>
<td>88</td>
<td>1.70</td>
<td>0.217</td>
<td>2.95</td>
<td>17.13</td>
<td>2.83</td>
</tr>
<tr>
<td>6.</td>
<td>400</td>
<td>6</td>
<td>11</td>
<td>60</td>
<td>2.5</td>
<td>0.312</td>
<td>2.88</td>
<td>13.133</td>
<td>2.90</td>
</tr>
</tbody>
</table>
Table 2. Observation table for LPG.
Now similar to that of petrol, readings were obtained for LPG as well, with the same rpm and similar load put to test.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>RPM</th>
<th>Load (w-s) (KG)</th>
<th>Manometric reading (cm)</th>
<th>Time for 20 gm LPG consumption (sec)</th>
<th>mf * 10^{-4} (kg/sec)</th>
<th>BP (KW)</th>
<th>BSFC (Kg/kw hr)</th>
<th>ma/mf</th>
<th>Thermal efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>200</td>
<td>4</td>
<td>0.8</td>
<td>130</td>
<td>1.53</td>
<td>0.047</td>
<td>5.30</td>
<td>4.04</td>
<td>1.38</td>
</tr>
<tr>
<td>2.</td>
<td>200</td>
<td>6</td>
<td>1</td>
<td>116</td>
<td>1.72</td>
<td>0.0178</td>
<td>3.96</td>
<td>4.91</td>
<td>1.85</td>
</tr>
<tr>
<td>3.</td>
<td>300</td>
<td>4</td>
<td>0.5</td>
<td>126</td>
<td>1.58</td>
<td>0.0717</td>
<td>3.64</td>
<td>4.75</td>
<td>2.01</td>
</tr>
<tr>
<td>4.</td>
<td>300</td>
<td>6</td>
<td>0.6</td>
<td>114</td>
<td>1.75</td>
<td>0.107</td>
<td>2.69</td>
<td>4.34</td>
<td>2.72</td>
</tr>
<tr>
<td>5.</td>
<td>400</td>
<td>4</td>
<td>1.5</td>
<td>104</td>
<td>1.92</td>
<td>0.0956</td>
<td>3.33</td>
<td>6.73</td>
<td>2.20</td>
</tr>
<tr>
<td>6.</td>
<td>400</td>
<td>6</td>
<td>1.4</td>
<td>100</td>
<td>2</td>
<td>0.143</td>
<td>2.30</td>
<td>8.22</td>
<td>3.18</td>
</tr>
</tbody>
</table>

The Engine and Fuel Test set up.
6. FORMULAS USED IN CALCULATION

1) TORQUE (T) = (w-s) * g * radius (r)
2) Brake power / b.p (KW) = (2 * π * N * T) / (60 * 1000)
3) BSFC (kg/KW-hr) = (mf *3600) / B.P
4) Brake thermal efficiency (%) = (B.P/mf * cv) * 100
5) Air /fuel ratio = ma / mf

Sample Calculations (for load 5 kg and 300rpm):

Ambient temperature / (Ta) = 303 K
Universal gas constant / (R) = 287KJ/kg K
Density of air = 1.165 kg / m³
Air pressure (Pa) = 1.013 * 10^5 bar
Diameter of orifice (d) = 0.0125m
Area of orifice/A = π/4 * d² = 1.227 * 10⁻⁴ m²
Torque = (5-1) * 9.81 * 0.0825 N·m = 2.2857 N·m
Brake power = (2 * π * 300 * 2.2857) / ( 60 * 1000 ) Kw = .0717 Kw

For Petrol:

Volume of air / (Va) = cd * A * (2* g * ha )⁰.⁵
Va = 1.615 * 10⁻³ m³/sec
Manometric of air / (ha) = (hw * ρw) / ρa = (15 - 12.3) * 992.2 / ( 100 * 1.165 )
= 22.99 m
Volume of fuel / Vf = ( 20 * 10⁻⁶ ) / t
Mass flow rate of air / ma = Va * ρa = 1.881 * 10⁻³ kg / sec
Mass fuel consumption / mf = Vf * pf = 20 * 10⁻⁶ / 228 = 6.56 * 10⁻⁵ kg /sec
BSFC = ( 6.56 * 10⁻³ * 3600 ) / 0.0717 kg / Kw-hr = 0.329 kg /KW-hr
Air fuel ratio (ma / mf) = 1.881 * 10⁻³ / 6.56 * 10⁻⁵ = 12.936
Brake thermal efficiency / η_Bth = ( 0.0717 / 6.56 * 10⁻³ * 42000 ) * 100 = 26.01%

For LPG:

Va = cd * A * ( 2* g * ha )⁰.⁵ = 6.95 * 10⁻³ m³/sec
Mass flow rate of gas / mg = 1.59 *10⁻⁴ kg / sec
ma = 6.95 * 10⁻⁴ kg /sec
ma / mf = 4.75
BSFC = 7.9 kg /KW- hr
η_Bth = 0.734%

7. RESULT AND DISCUSSION

Taking into consideration similar standards, the difference in the brake thermal efficiency is evident. With the increasing load, the fuel consumption is increasing.
The above graph shows the change of the brake thermal efficiency with respect to the load and LPG is having less brake thermal efficiency than Petrol at different load condition at 300rpm.

The graph shows the change of brake thermal efficiency with respect to load at 200rpm and superiority of LPG over Petrol.
Same graph at 400rpm but here the brake thermal efficiency for LPG is greater than Petrol for load condition of 6kg and 6.5kg respectively.

8. SCOPE FOR FUTURE WORK

The scope of future work in this area of research project is very prominent. The field of automobiles and its innovations are ever increasing and booming in this genre.

1. It will prove to be a great asset for further research and experimentation.
2. If a proper ECM is synchronized with the working engine it can lead to direct injection system which can be more effective and efficient as compared to both the carburetor as well as the port injection system.
3. There are also provisions for running the engine in other fuels like that of CNG and alcohol blends.
4. A more recognized and eminent cooling system can be hired and better efficiency can be obtained.

9. CONCLUSIONS

From, the performance readings and performance curves it is clear that by using LPG where we find definite scope of increased efficiency in most aspect. The cost factor is undoubtedly a bit on the higher side, but the showcasing of the fuel effectiveness proves to be every economical in case of LPG than petrol. This kind of system is yet to get implemented into the commercial arena, but since the research works in the automobile sector is ever
booming, sooner it will lead to a great worker of economy. It can be concluded by saying that
the LPG system incorporated, and have successfully proved it to be more beneficial than
conventional petrol engine with respect to cost as LPG is cheaper than petrol.

From the testing data we can conclude that brake specific fuel consumption of LPG is
15-18% more and brake thermal efficiency 7- 8% more than Petrol. By doing various test on
our project we concluded following performance of LPG versus Petrol (calculated on commercial/Auto LPG).

<table>
<thead>
<tr>
<th>Petrol Km / Ltr</th>
<th>Rs. / Km</th>
<th>LPG Km./kg</th>
<th>Rs. /Km</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.06 Km/ Ltr.</td>
<td>Rs.2.90 /Km</td>
<td>28.5 Km/ kg</td>
<td>* Rs.1.01 /Km</td>
<td>* LPG 2.87 times cheaper than Petrol</td>
</tr>
</tbody>
</table>

References

[8] DB Kittelson, 1996. DOI:10.4271/960600

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