Optimization of Ignition Parameters for Enhancement of Performance and Emissions of a Four Stroke Single Cylinder SI Engine Fueled with CNG

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Abstract — The study on alternative fuels has become important due to depletion of petroleum products and its major involvement for pollutants. In this work Compressed Natural Gas is used to run light duty SI engine. The Performance and Emission of the CNG fuelled engine for different Spark Plug Gap and Spark Plug Projection have been evaluated. The experiments were performed using 3 different spark plug gaps (SPG) (0.4, 0.6 and 0.8 mm) and 3 different Spark Plug Projections (SPP)(0,0.5 and 1 mm) at the constant speed of 3000 rpm and varied load conditions. The maximum efficiency values and minimum emission were obtained for 0.8 mm Spark Plug Gap and 1 mm Spark Plug Projection.

Keywords: SI Engine, CNG Engine, Spark Plug Gap, Bi-Fuel Vehicles, Ignition system

I. INTRODUCTION

Petrol having alarming deteriorating rate and excessive emission rate demands for alternative fuel like CNG, which is easily available in India, to fulfill the energy needs of the country. The properties of CNG such as higher Calorific Value, higher Auto ignition Temperature and safety along with its feasibility makes it a favourable alternative fuel for SI engine. Kirti Bhandari et al [1] showed that two types of NG engines are primarily studied: Petrol having alarming deteriorating rate and excessive emission rate demands for alternative fuel like CNG, which is easily available in India, to fulfill the energy needs of the country. The properties of CNG such as higher Calorific Value, higher Auto ignition Temperature and safety along with its feasibility makes it a favourable alternative fuel for SI engine. Natural Gas has considerably higher Octane Number than petrol and has very low Cetane Number when compared with diesel fuel [2]. Hence it is more suitable for SI engine rather than CI engine [3]. A Four stroke SI engine running on CNG has a lower volumetric efficiency as compared with Petrol fuelled engine [4]. R.R.Raine et al. [5] measured the exhaust gas temperature, piston crown, spark plug body, exhaust valve and cylinder head temperature in natural gas and gasoline fuelled engine. The results showed that the temperature of combustion chamber for natural gas fuelling was lower than that for gasoline fuelling. The exhaust gas temperature was lower for natural gas operation than that for gasoline operation. The exhaust valve temperature with gasoline fuelling was higher than that with natural gas fuelling. E Ramjee et al. [6] showed that for all range of speeds, Except thermal efficiency the other performance parameters viz BMEP, Torque, Power and BSFC are decreased for CNG fuelled engine compared to petrol fuelled engine; Except NOx the other emission characteristics such as CO, CO2, and HC are decreased. Marek Flekiewicz et al [7] showed that for SI engine running on CNG, the spark timing has to be changed for maximum brake torque conditions. Bilge Albayrak depicted that for lean mixture combustion, the torque and efficiency of the engine increases with increase in spark plug gap and after certain value of gap it starts decreasing again [8].

The review showed that ignition parameters affect the performance of the engine. So, SI engine converted to CNG engine from petrol engine the ignition Parameters also have to be changed. This will improve the performance as well as emission level of the SI engine. The ignition Parameters that is to be changed are Spark Plug Gap and Spark Plug Projections. Spark Plug Gap is to be increased and Spark is further projected in to the engine cylinder for CNG fuelled SI engine.

In the present work the investigational analysis is carried out on a four stroke single cylinder air cooled type petrol engine to calculate performance and exhaust emissions of the test engine. All tests were carried out for Petrol and CNG as well as different Spark Plug Gaps and Projections.

II. EXPERIMENTAL SETUP

The experiments were carried out at constant speed of 3000 rpm and different load conditions to measure performance and emissions of the engine. Various components used in the test facility are: Single Cylinder Petrol Engine, Rope Brake Dynamometer, Exhaust Gas Analyzer, Fuel Consumption Device, Radiation Pyrometer, Digital Tachometer, CNG conversion kit, CNG Gas Cylinder. The engine Specifications are listed in Table 1.

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Bajaj Pulsar 150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>4-stroke, single cylinder SOHC</td>
</tr>
<tr>
<td>Valve train</td>
<td>2 valves</td>
</tr>
<tr>
<td>Bore x stroke, mm</td>
<td>57 x 56.4mm</td>
</tr>
<tr>
<td>No. of cylinders</td>
<td>One</td>
</tr>
<tr>
<td>Displacement</td>
<td>143.91 cc</td>
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<tr>
<td>Compression ratio</td>
<td>9.5 : 1</td>
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<tr>
<td>Carburettor</td>
<td>Ucal Mikuni BS26</td>
</tr>
<tr>
<td>Max. Power, kW @ rpm</td>
<td>11.82bhp@8500rpm</td>
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<tr>
<td>Max. Torque, Nm @ rpm</td>
<td>10.8Nm@7000rpm</td>
</tr>
<tr>
<td>Ignition</td>
<td>Electronic CDI System</td>
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<tr>
<td>Idle Speed</td>
<td>1300 rpm</td>
</tr>
<tr>
<td>Spark Plug</td>
<td>Champion RG4HC</td>
</tr>
</tbody>
</table>

Table 1: Engine Specifications

The Tests have been carried out for both CNG and Petrol fuels and for three sets of spark plug Gap and Spark
Plug Projections for CNG engine. For CNG conditions the engine were fitted with CNG Kit. The following parameters were found for each practical: Brake Specific Fuel Consumption, Brake Thermal Efficiency, Exhaust Gas Temperature, Volumetric Efficiency and emission of HC and CO in Exhaust.

III. RESULTS AND DISCUSSION

The experiments were carried out at constant speed of 3000 rpm and the load on the engine was varied from no load to 2, 4, 6 and 8 kg of load. The experiments were carried out for Spark Plug Gap of 0.6, 0.7 and 0.8 mm as well as for Spark Plug Projections of 0, 0.5, 1 mm. Various parameters pertaining to performance and emissions are calibrated. Fig. 1 shows a graph plotted between BSFC and Brake Power for different Spark Plug Gap. Fig. 2 shows the similar for different Spark Plug Projections. From the Graphs it is observed that BSFC for CNG engine is higher than Petrol engine. As the Spark Plug Gap Increases the Fuel consumption of CNG decrease about 11.83 % at maximum and 8.32 % at minimum. With increase in Spark Plug Projections the BSFC decreases about 12.38 % maximum and about 6.55 % minimum.

![Fig. 1: Variation in BSFC with Brake Power for different Spark Plug Gaps](image1)

![Fig. 2: Variation in BSFC with Brake Power for different Spark Plug Projections](image2)

![Fig. 3: Variation in BTE with Brake Power for different Spark Plug Gaps](image3)

![Fig. 4: Variation in BTE with Brake Power for different Spark Plug Projections](image4)

![Fig. 5: Variation of Exhaust Gas Temperature with Brake Power for different Spark Plug Gaps and Spark Plug Projections](image5)

![Fig. 6: Variation of Exhaust Gas Temperature with Brake Power for different Spark Plug Gaps and Spark Plug Projections](image6)

![Fig. 7: Variation in Volumetric Efficiency with Brake Power for different Spark Plug Gaps and Spark Plug Projections](image7)

![Fig. 8: Variation in Volumetric Efficiency with Brake Power for different Spark Plug Gaps and Spark Plug Projections](image8)

![Fig. 9: Emission of CO with Brake Power for different Spark Plug Gaps and Spark Plug Projections](image9)

![Fig. 10: Emission of CO with Brake Power for different Spark Plug Gaps and Spark Plug Projections](image10)

Fig. 3 and 4 show the Graph between Brake Thermal Efficiency and Brake Power for different Spark Plug Gaps and Spark Plug Projections respectively. The maximum BTE achieved for CNG was 16.74 % at 0.8 mm Spark Plug Gap and 17.13 % at 1 mm Spark Plug Projections. This is due to increased speed of burning in the combustion chamber.

Fig. 5 and 6 show the variation of Exhaust Gas Temperature with Brake Power for different Spark Plug Gap and different Spark Plug Projections. Increase in spark Plug Gap and Spark Plug Projections decreases the Exhaust Gas Temperature. This is due to increased combustion efficiency.

Fig. 7 and 8 show the variation in Volumetric Efficiency with Brake Power for different Spark Plug Gap and Spark Plug Projections. Volumetric Efficiency was higher for Petrol when compared to CNG for all load and speed range. At higher Spark Plug Gap combustion time is lower and this lower combustion time results in complete combustion and more amount of gases are rejected in the exhaust.

Fig. 9 and 10 shows the emission of CO with Brake Power for different sets of Spark Plug Gap and Spark Plug Projections. As both the ignition parameters increases the CO
emissions decreases. This is due to better combustion efficiency of the engine. Fig. 11 and 12 show the emission of HC with Brake Power for different sets of Spark Plug Gap and Spark Plug Projections. For increased Spark Plug Gap and Projections HC emissions decreased. The reduction in the HC emission was maximum of a 14.14 % at 0.8 mm Spark Plug Gap and about 10.52 % at 1mm Spark Plug Projections.

Fig. 5: Variation in EGT with Brake Power for different Spark Plug Gaps

Fig. 6: Variation in EGT with Brake Power for different Spark Plug Projections

Fig. 7: Variation in Volumetric Efficiency with Brake Power for different Spark Plug Gaps

Fig. 8: Variation in Volumetric Efficiency with Brake Power for different Spark Plug Projections

Fig. 9: Variation in CO emission with Brake Power for different Spark Plug Gaps

Fig. 10: Variation in CO emission with Brake Power for different Spark Plug Projections
IV. CONCLUSION

The performance and emission of the SI engine when fuelled with CNG decreases compared to Petrol. The optimization of Ignition Parameters increases the performance and further reduces the emission of the SI engine when fuelled with CNG.

The Brake Specific Fuel Consumption decreased with increase in Spark Plug Gap as well as Spark Plug Projections. BSFC decreased about a 9.65 % at full load and 1500 rpm and about a 9.73 % at 4 kg load and 3000 rpm for the spark Plug Gap of 0.6 mm compared to 0.6 mm Spark Plug Gap. BSFC decreased about a 7.18 % at full load and 1500 rpm and about an 11.28 % at 6 kg of load and 3000 rpm for the Spark Plug Projection was increased from 0 mm to 1 mm.

Engine operations with CNG fuelled engine for different Spark Plug Gap and Projections were compared and the key observations made are: For all range of loads, except BTE and Volumetric Efficiency other Performance Parameters such as BSFC, EGT and Volumetric Efficiency were increased with increase in both Spark Plug Gap and Projection. Engine emission Parameters such as CO and HC emission decreased with increase in Spark Plug Gap and Projection.

The Performance and emission was enhanced greatly in CNG fuelled engine for 0.8 mm spark Plug Gap, when Spark Plug Projections were kept Constant of 0 mm. Similarly, The Performance and Emission were highest for 1 mm Spark Plug Projections at constant Spark Plug Gap of 0.6 mm.

REFERENCES