Experimental Investigation on Single Cylinder Digital Twin Spark Ignition using LPG at Different Compression Ratios

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Abstract— Depletion of fossil fuels due to increase in demand and higher exhaust emissions are the driving force for many researchers to find alternative fuel for SI engine. There has been a lot of research work carried under many initiatives and schemes to make environment sustainable with cleaner emission. There are many renewable energy sources available to use as alternative for fossil fuel. Among this gaseous alternative fuel like LPG offer promising opportunity with clean burning and fewer emissions. Lesser harmful post combustion elements and equivalent efficiency as fossil fuel of LPG indicates as future promising alternative fuel. This work evaluated an experimental study on single cylinder twin spark ignition engine using both gasoline and LPG at the fixed spark timings of 30º BTDC and 26º BTDC. The engine is equipped with LPG gas kit which includes gas cylinder, vaporizer and solenoid valve to supply LPG in gaseous form to run the engine smoothly. The performance and emission characteristics of test engine are evaluated at two different compression ratios using LPG and gasoline as fuel. The experimental results revealed that, brake thermal efficiency increases with decrease in brake specific fuel consumption. The exhaust emissions such as CO, HC, and CO_2 and NO_x decreased remarkably with LPG compared to gasoline.

Index Terms— LPG, HC, CO, CO_2, NO_x.

I. INTRODUCTION

In recent years, increase in market demand has driven the researchers to look for alternative to fossil fuels to meet stringent exhaust emission norms. The gaseous fuels can be easily used in SI engines with low emissions with improved performance parameters. They exhibit wide range of ignition limits helps in get homogeneous mixture with air will improve the combustion efficiency. Gaseous fuels helps to run the engine smoothly at lean mixture condition. Moreover, gaseous fuels produce less carbon based emissions due to higher hydrogen to carbon ratio. LPG is readily available petroleum based fuel can be easily utilized in SI engine in urban areas where the distribution network is already established. LPG is the by product in oil refinery process includes propane and butane as primary composition [1, 2]. Many researchers worked on LPG, concluded in their work that, LPG based vehicles emits less exhaust emissions compared to gasoline vehicles [3]. LPG engines have showed remarkable reduction in HC, CO and NO_x compared to petrol engines and substantially reduction in CO_2 due to high hydrogen/carbon ratio [4, 5]. It has higher octane number than gasoline allows running the engine at higher compression ratio without knocking. LPG can be liquefied in a low pressure range of 0.7 to 0.8 MPa due to its higher heating value. Many researchers have worked on use of LPG in SI engine reported favorable results from emission perspective.

II. EXPERIMENTAL WORK

A four stroke single cylinder digital twin spark ignition engine is used in this work for investigating the performance and emission analysis. Specification of the test engine is given in table.1. The engine is tested for both petrol and LPG at different compression ratios with respect to various engine loads. The test engine was facilitated with eddy current loading, ignition angle adjustment system, fuel consumption measurement and exhaust emission measurement. The detailed layout of the experimental setup is presented in the Fig.1.

Table 1 Engine Specification

Engine	Kirloskar
Rated Power	5 HP
Bore Dia.	87.5 mm
Stroke length	110 mm
Connecting rod length	234 mm
Rated Speed	1500 RPM
Compression Ration	6 – 10
Cooling	Water Cooled
Mode	Dual Fuel

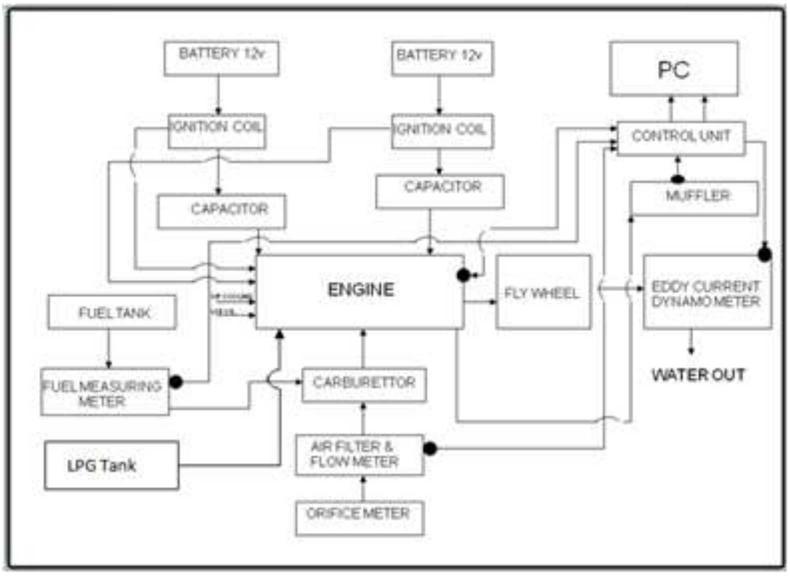

Fig. 1. Experimental layout.

III. PERFORMANCE STUDY

Figure 2 clearly elaborates the influence of compression ratio on gasoline and LPG at various engine loads. As the load varied from 2 kg to 10 kg fuel consumption has been decreased for both gasoline and methanol. The reason could be increased combustion efficiency with increased engine load due to higher in-cylinder temperature. It is also observed that, LPG has shown less specific fuel consumption compared to gasoline for both compression ratios. This trend has been observed because LPG has a higher heating value and higher stoichiometric air-fuel ratio compared to gasoline [6, 7].

The variation of brake power in case of gasoline and LPG fueled engine at different load conditions is presented in the Fig. 3. The results are plotted at two different compression ratios 6/1 and 8/1. Increase in compression ratio increases power for both gasoline and LPG. This might be because of increasing the combustion chamber temperature and larger mechanical power output by available fuel. It is observed from the results that, LPG fueled engine suffer on power produced compared to gasoline in both the compression ratios. This is because LPG is a gaseous fuel which enters the combustion chamber in gaseous form will not have cooling effect and having less density reduces the volumetric efficiency. The decrease in power at maximum engine load was found to be 16.22% and 7.88% at 6:1 and 8:1 compression ratios respectively.

The effect of compression ratio on brake thermal efficiency for both LPG and gasoline is presented in the Fig. 4. It is very clear that, thermal efficiency increases with increase in compression ratio. Higher the compression ratio, higher will be the conversion of chemical energy into the mechanical output. The increase in compression ratio increases the combustion efficiency due to its higher octane number can be another reason in improving efficiency [8]. It is also observed that, efficiency has been increased for LPG compared to gasoline. At the maximum engine load, the increase in efficiency is about 23.22% and 19.33% at compression ratios 6:1 and 8:1 respectively. The reduction in specific fuel consumption and higher heating value can be considered as third reason for this improvement.

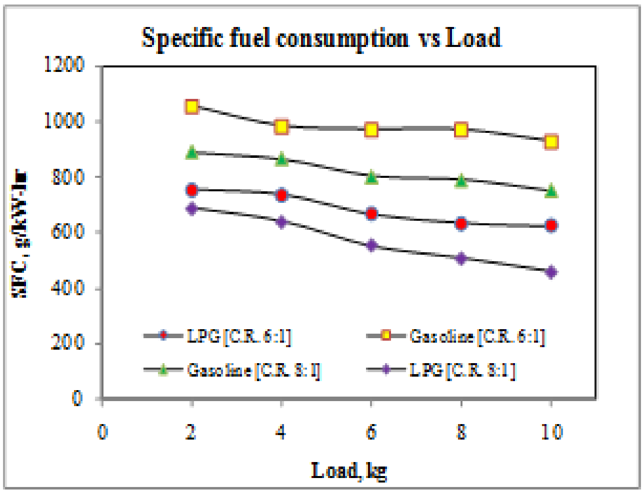

Fig. 2. Specific fuel consumption with respect to load.

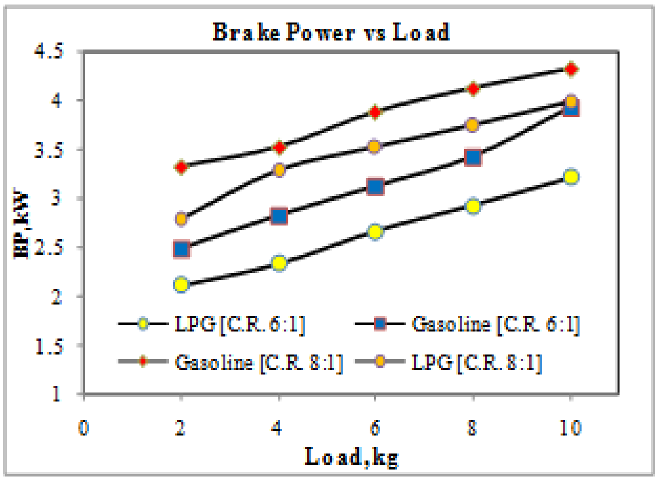

Fig. 3. Brake power with respect to load.

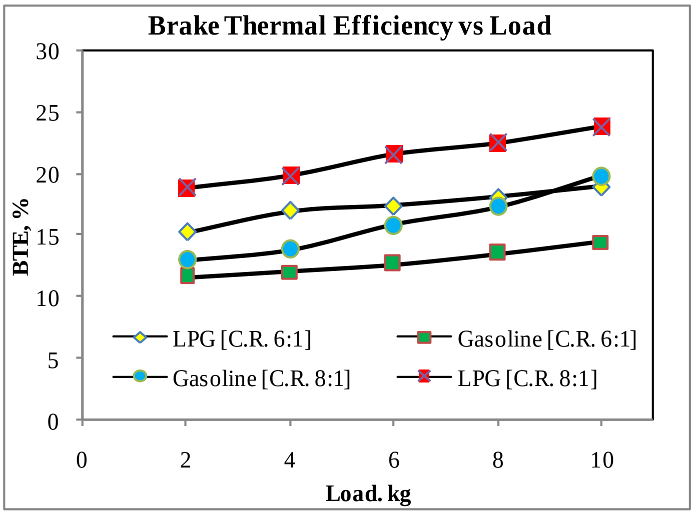

Fig. 4. Brake thermal efficiency with respect to load.

IV. EMISSION STUDY

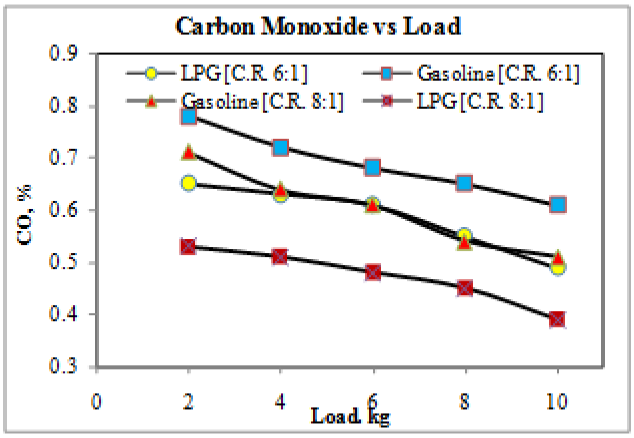

Fig. 5. Carbon monoxide with respect to load.

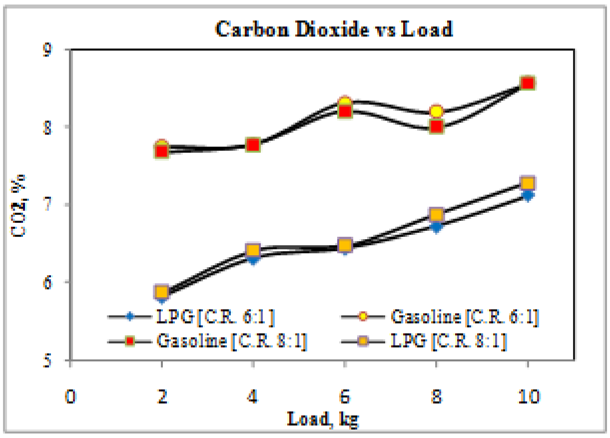

Fig. 6. Carbon Dioxide with respect to load.

The variation of carbon monoxide emission for gasoline and LPG fuel at different load conditions is presented in the Fig. 5. As the load increased from 2 kg to 10 kg, the carbon monoxide emission showed decreasing trend. The reduction in CO emission can also be observed for increasing the compression ratio. CO emission is mainly due to the incomplete combustion and insufficient oxidation temperature at the later part of the combustion chamber. LPG is a gaseous fuel will not offer cooling effect during the combustion like gasoline might be the reason for reduction in CO emission for LPG fuel [9]. The decrease in CO emission for LPG fuel at maximum load condition was found to be 19.21% and 23.33% at compression ratios of 6:1 and 8:1 respectively.

The carbon dioxide variation with respect load at two different compression ratios is elaborated in the Fig. 6. It can be observed that, CO_2 emission increases as load increases in both the compression ratios. Production of CO_2 is inverse of CO emission. As we observed in the previous figure, CO reduces for LPG increases the CO_2 by maximum conversion of carbon into CO_2 instead of coming out at exhaust as CO. The higher C/H ratio of LPG is also a reason for decrease in CO_2 emission in case of LPG fuel. The decrease in CO_2 emission is about 16.82% and 14.44% at the compression ratios 6/1 and 8/1 respectively.

Incomplete combustion, lower cylinder temperature and improper mixing of air- fuel are the common reasons for hydrocarbons emission in ICE. Unburned hydrocarbon emission at different load conditions for both LPG and gasoline fuel is presented in the Fig. 7. It is very clear from the figure that, hydrocarbon emission decreases for LPG in both the compression ratios. It is also observed that as the load increased, hydrocarbon emission decreased. Increasing the load increases in-cylinder temperature helps in complete combustion ends with lower HC emission.

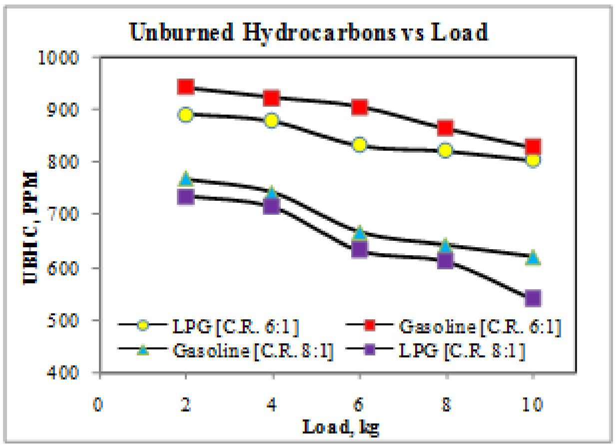

Fig. 7. Unburned hydrocarbons with respect to load.

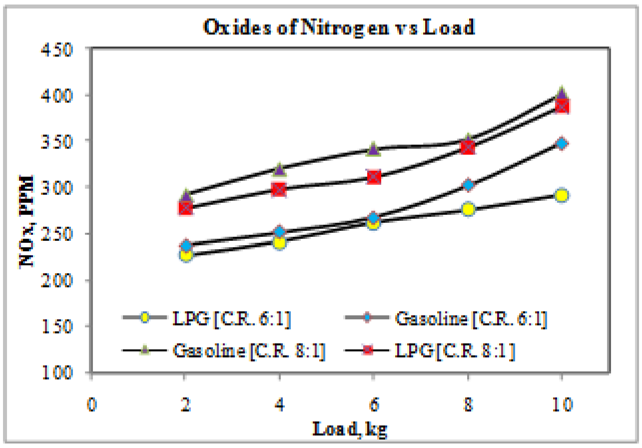

Fig. 8. Oxides of Nitrogen with respect to load.

V. CONCLUSION

Emission of NO_x with respect to load in case of LPG and gasoline for two different compression ratios is elaborated in the Fig. 8. Increase in compression ratio increases NO_x emission due to increase in cylinder temperature. The increase in NO_x emission by increasing the compression ratio is about 15.12% and 27.12% in case of gasoline and LPG fuel at the maximum engine load. At the compression ratio 6/1, reduction in NO_x emission for LPG over gasoline fuel is 16.02%. There is 8.12% reduction in NO_x emission for LPG fuel over gasoline at compression ratio 8/1.

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