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Computational and Parametric Investigation on Single Cylinder SI Engine-Based Generator to Improve Its Performance and Emission Charectoristics as Per the Future Emission Norms

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Abstract

This work is based on single cylinder SI engine based generator,which basically works on Gasoline and LPG in Dual fuel mode. The main purpose of this work is to use Alternative fuel, for reducing the emissions of the generator in dual fuel mode. As the engine is dedicated to Gasoline engine,which is conventional fuel. So power is comparativily increasing in case of gasoline engine,but emissions are more as compared to Alternative fuels. Since alternative fuel is having less number of carbon atoms. So, less formation of NOx, HC and CO emissions occurs. Our main focus is on emission formation. We are trying to reduce the emissions as per the future emission norms. Although power is comparatively going down in case of alternative fuel,but emission formation are less. So in order to investigate the performance and emissions charecteristics we are using AVL boost software for predicting the performance of SI engine and emissions,when using the engine in dual fuel mode.

Keywords: alternative fuels, AVL boost, emissions, SI engine, simulation

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INTRODUCTION

Most of the natural gas is found in the upper part of the oilwells or gas wells.It mainly consists of methane (75% to 95%) with small quantities of ethane,propane,and higher hydrocarbons.It may also contain small quantities of nitrogen,carbon dioxide and hydrogen sulphide.It is nearly odourless and colourless. During the refining process of petroleum,considerable amount of propane and butane gases are produced.Propane gas liquifies at 8.8 bar and butane gas liquifies at 2.1 bar at atmospheric temperature of 21.1C. Natural-gas processing is a complex industrial process designed to clean raw natural gas by separating impurities and various non-methane hydrocarbons and fluids to produce what is known as pipeline quality dry natural gas. [1] The liquified gas can be stored in steel cylinders and these gases are suitable for domestic and industrial applications. A powerful odorant, Ethyl Mercaptan is added, in order to detect leak on the container (tank) or at any connection, it made leaking can be easily detected. It is generally accepted that the emission form a LPG powered vehicle are less than those from the unleaded petrol (ULP) fuelled equivalent.[2–12]

Result from corroborated by Klausmeier and Billick[4] Wu et al.[5] and Newkirk et al.[6] presented measured data showing that NOx emission from LPG fuels are lower compared to ULP. It is also comparably light and cost effective. Ceviz and Yuksel in their study on cyclic variation on LPG when fuelled as lean burn SI engine is more suitable fuel when using as lean Combustion engine Compared with

Gasoline. The important Characteristics' of LPG are, LPG is having high Octane No which is 112 for pure propane that enables it for using higher Compression ratios to be used and can improve thermal efficiencies.[2–8] There is a several alternative method to improve the performance for the engine fuelled by LPG due to the losses of volumetric efficiencies. One of these methods can be implementing; increase compression ratio (CR) under natural aspirated operation and/or apply turbo charger and/or supercharger.[10]

SIMULATION SETUP

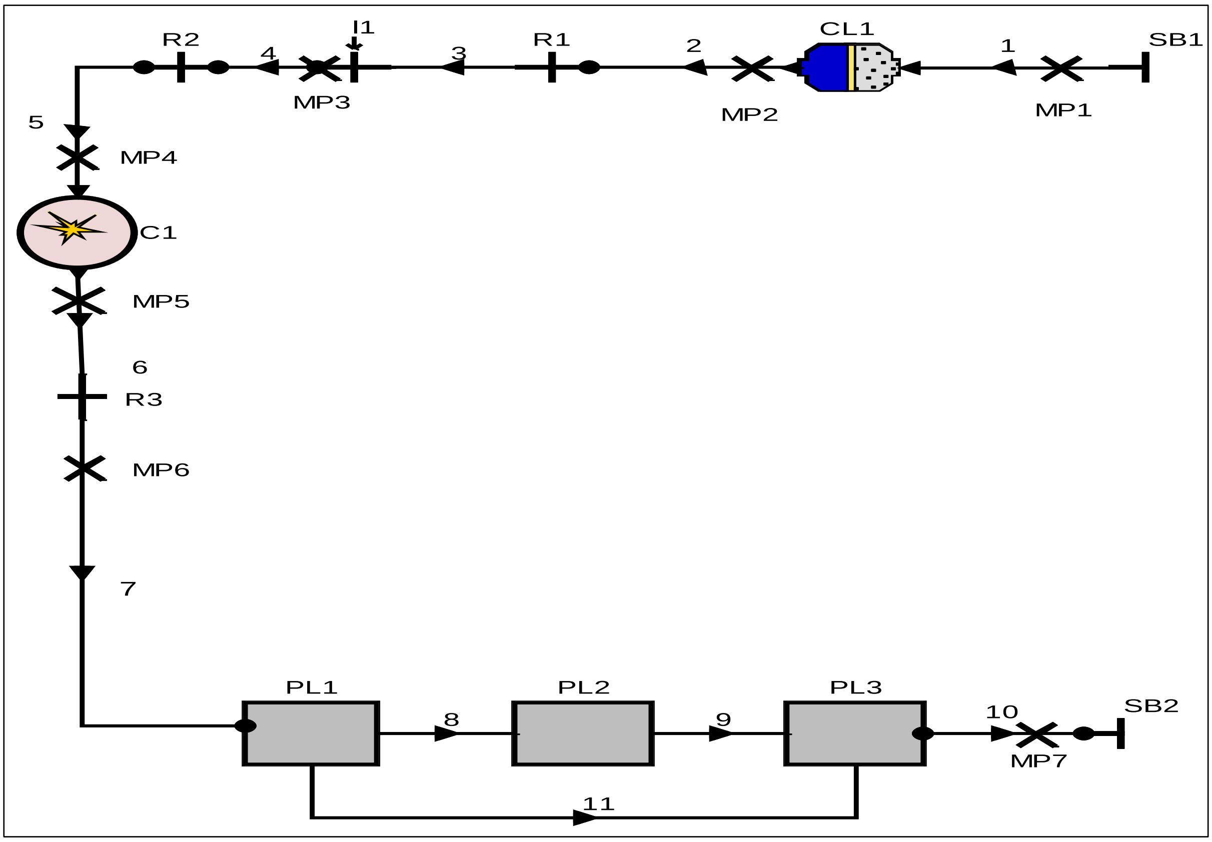

Fig. 1. *Layout of Gasoline Engine Model.*

The one Dimensional Engine Simulation model is made by using AVL Boost Software, and after developing the model it is made to study the performance of engine working on Gasoline and LPG in duel fuel mode.

The engine model used in this simulation was performed on a four stroke, Single cylinder spark ignition engine without catalytic convertor and port fuel injection. This Engine model has been calibrated by AVL Boost and the Layout is shown in above diagram, and specifications of engine are shown in Table 1.

The various elements of AVL Software enables user to develop a model of one-Dimensional test engine bench setup by using the predefined elements which are provided in the Software toolbox. All the elements are joined by the various connectors for making the complete engine model by using the pipelines.

In Figure 1, E1 represents the engine while C1, represent the single cylinder of the engine. MP1 to MP7 represent the measuring points. PL1 PL2 and PL3 represent the plenum. SB1 and SB2 represent system boundary.

And the flow pipes are from 1 to 10, CL1 is cleaner, R1 and R3 are flow restrictions.

Table 1. *Engine Specifications.*

Criteria	Description
Make	Briggs and straton
Type	Air cooled 4 stroke OHV gasoline
Displacement	206cc
Compression ratio	9
Bore and stroke	65.09 × 61.91
Maximum HP	6.5
Cooling system	Air cooled
Ignition system	Magnetron electronic

MATHEMATICAL MODEL

Mathematical models for spark–ignition engines can be divided into two main groups- thermodynamic and dimensional models. Thermodynamic models can in turn be classified.[13]

In two sup groups – single and multizone models – whereas dimensional models can be divided into one and multidimensional models.

In single-zone models the cylinder charge is assumed to be uniform in pressure, temperature, and composition. These models can be used as diagnostic (heat release analysis) or predictive tools. Because of their simplicity, single zone models, can account for mass flows into and out of crevices. However they ignore the flame propagation and combustion chamber geometry.

We can use single zone models as predictive tools, but the mass burning rate should be specified. And the mass burning rate depends on the Engine Geometry, Combustion Duration, Ignition angle, Residual mass, and equivalence ratio, etc. Therefore, tuning may be required to predict the pressure diagrams in different engines or in the same engine operating under different conditions.

Multi zone models attempt to resolve the combustion phenomena in a more physical manner than do single-zone models. The combustion chamber is generally divided into burnt and unburnt regions; sometimes thermal boundary layers in the burnt and unburnt gases are also considered.

The cylinder charge is frequently assumed to be composed of ideal gases (frozen in the unburnt-gas region and in chemical equilibrium in the burnt-gas region), and the first law of thermodynamics, equation of state, and conservation of mass and volume are applied to the burnt and unburnt gases.

Single – Zone Models

In single zone models temperature, pressure, and composition of cylinder charge are assumed to be uniform. The above model defines its state. The state of the Cylinder charge in terms of average properties do not distinguish between both burnt and unburnt gases and it assumes cylinder charge as homogenous.

Multizone models permit a more accurate treatment of the thermodynamic properties of the cylinder mixture; the burnt and unburnt gases are considered as separate thermodynamic systems that are uniform in composition and state. However the geometry of each zone must be tracked in order to calculate the heat transfer and composition of the burnt and unburnt gases are considered as separate thermodynamic systems that are uniform in composition and state.

Combustion in single-zone models can be considered as a heat addition process, and the chamber charge is regarded as a simple fluid. The first law of thermodynamics applied to an open system can be written as

$$\frac{d_{(me)}}{d_{\theta}} = -p\frac{dV}{d\theta} - \frac{dQ}{d\theta} + \sum \dot{m}i\ hi \qquad e = e^0 + \int_{T_0}^{T} C_v \ \ dT \qquad (1)$$

where p, T, and m are the pressure, temperature, and mass of the cylinder charge, respectively is the mixture specific internal energy; Cv is the specific heat at constant volume; V is the combustion chamber volume; dQ/dθ represents the heat losses; hi is the specific enthalpy of the gases flowing into the cylinder with a mass flow rate equal to ṁi;T0 is a reference temperature; e^0 is the internal energy of formation at the reference temperature T0; and θ is the crank shaft angle.

In the absence of injection and flows into crevices, dm/dθ = 0.In premixed charge engines, there are flows into and out of crevices (i.e., volumes between the piston, cylinder wall, and piston rings and the spark plug threads).The crevices can be modelled as a single volume at the cylinder pressure or as a series of volumes, connected by restrictions to simulate the piston ring- cylinder wall region and blow by.

Equation (1) can be written as

$$\frac{dQ_{CH}}{d\theta} = mC_v\frac{dT}{d\theta} + p\frac{dV}{d\theta} + \frac{dQ}{d\theta} + (h-e)\frac{dm_{CR}}{d\theta} \quad (2)$$

where dQCH /dθ represent the heat released by combustion, dmCR/dθ represents the mass flow rate into crevices, and h is the specific enthalpy.

Conservation of mass applied to the combustion chamber yields

$$\frac{dm}{d\theta} = -\frac{dm_{CR}}{d\theta} \quad (3)$$

When the cylinder pressure is high, $\frac{dm_{CR}}{d\theta} > 0$ and the value of h corresponds to that in the combustion chamber:

$$h = e + PV/m \quad (4)$$

However, during the expansion stroke, dmCR/dθ< 0 and the value of h is that of the gases contained in the crevices. If the crevice volume and temperature are assumed constant and the crevice pressure is equal to that of the cylinder charge, the mass flow rate into the crevices can be written as

$$\frac{dm_{CR}}{d\theta} = V_{CR}\ \frac{dp/d\theta}{RTw} \quad (5)$$

Where the crevice temperature was set equal to the temperature of the cylinder wall Tw and V*CR* is the crevice volume.

Equation (5) can be substituted into equation (2) and (3) to obtain an equation for the heat released by combustion once the heat transfer losses dQ/dθ are specified. Heat transfer correlations once the heat transfer losses dQ/dθ is specified.

MATERIALS AND METHODS

The Test Engine

The Briggs & Stratton variable compression ratio engine with direct current electric dynamometer is a four stroke air cooled OHV single cylinder petrol engine.

It has a 69.09mm cylinder bore and 61.19mm stroke, displacement 206CC, and magnetron electronic ignition system.

Experimental Setup

Fig. 2. *Generator Model AG 2500E.*

In Figure 2 the experimental set is mentioned. The AG 2500E Whispower single cylinder SI engine is used for experimental setup. This Generator is dual fuel engine, in which both LPG and

Gasoline is used as fuel, the main fuel tank of generator is made empty, and then the fuel is being send from the fuel tank of test rig, where blending of fuel can take place.

Since my work is based on single cylinder SI engine based generator, in which we are using LPG as an alternative fuel for checking the performance and exhaust emissions. Since LPG has less number of carbon atoms than Gasoline so emissions are comparatively going down as compared to conventional gasoline engine. The Gas Analyser is used for checking the emissions from the exhaust of the generator. Figure 3-4.

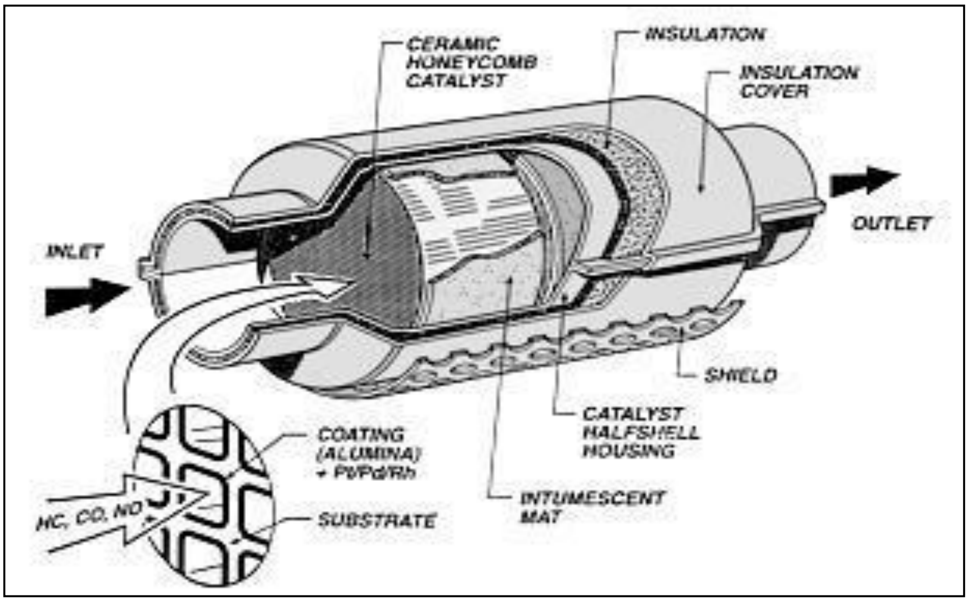

Fig. 3. *Gas Analyser*

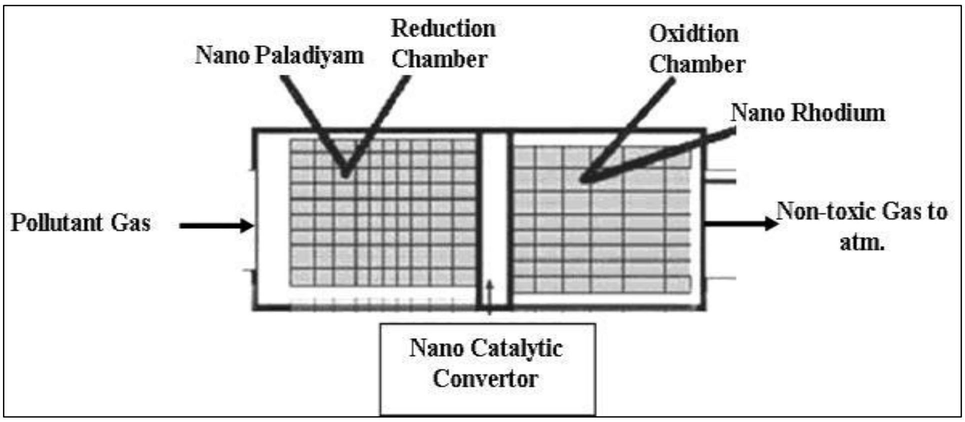

Fig. 4. *Three Way Catalytic Convertor.*

Vehicular Pollution and Catalytic Convertor

It is defined as the introduction of chemicals, particulate matter, or natural materials to the atmosphere that cause harm or discomfort to the living organisms. Due to the improvement in science and technology there is a drastic improvement in automobile production which results in more amount of harmful gas is let into the atmosphere. These gases react with the atmosphere and pollute it.

A "catalytic converter" is a device used to reduce the toxicity of emissions from an internal combustion engine. A catalytic converter converts the injurious noxious combustion products and it's by products into less-toxic substances. Catalysis is the process in which the rate of a chemical reaction is increased by means of a chemical substance known as a catalyst. Three-way catalytic converter is widely used in the vehicle industries.

The three-way catalytic converter is scheduled to perform three simultaneous tasks, a) palladium: reduction catalyst, b) rhodium: oxidation catalyst, and c) the control system Figure 3, as mentioned above, Surface area and pore size, Particle size distribution, Wash coat thickness & Adhesion.

The Reduction Catalyst

The reduction catalyst is the first stage of the catalytic converter. It uses Nano palladium to assist reduce the nitrogen oxide emissions. When such molecules come in contact with the catalyst, the catalyst rips the nitrogen atom out of the molecule and hold on to it, freezing the oxygen in the form of O2. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst, forming N2.

The Oxidization Catalyst

The oxidation catalyst is the next stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (Oxidizing) them over a nano rhodium catalyst. This catalyst aid the effect of the CO and hydrocarbons with the remaining oxygen in the exhaust gas.

Reduction of nitrogen oxides to nitrogen and oxygen

$2NOx \rightarrow xO_2 + N_2$

Oxidation of carbon monoxide to carbon dioxide,

$2CO + O_2 \rightarrow 2CO_2$

Oxidation of un-burnt hydrocarbons (HC) to carbon dioxide and water

$CxH2x + 2xO_2 \rightarrow xCO_2 + 2xH_2O$

Catalytic convertors are mainly used in the area of Petrol engine emission control, Diesel engine emission control, Food processing industries, Chemical manufacturing industries & Gas turbines.

RESULTS AND DISCUSSION

Brake Power

Figure 5 shows the plot between power and engine speed. This graph shows that, increasing engine speed increases the power for both gasoline and LPG as fuel. But comparatively power is increasing for Gasoline more than LPG.

This is due to the reason that engine is dedicated to Gasoline Engine only.

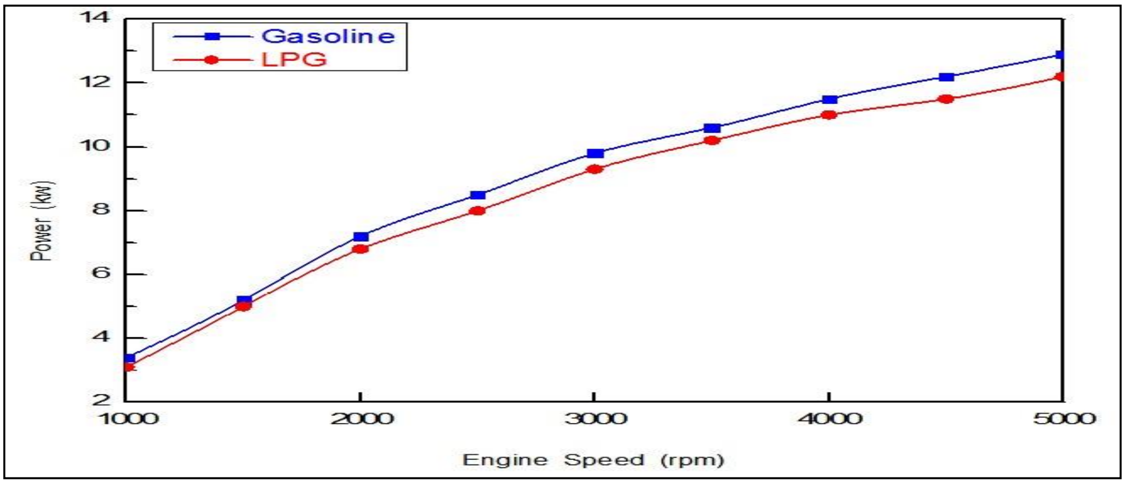

Fig. 5. *Graph Between Power and Engine Speed.*

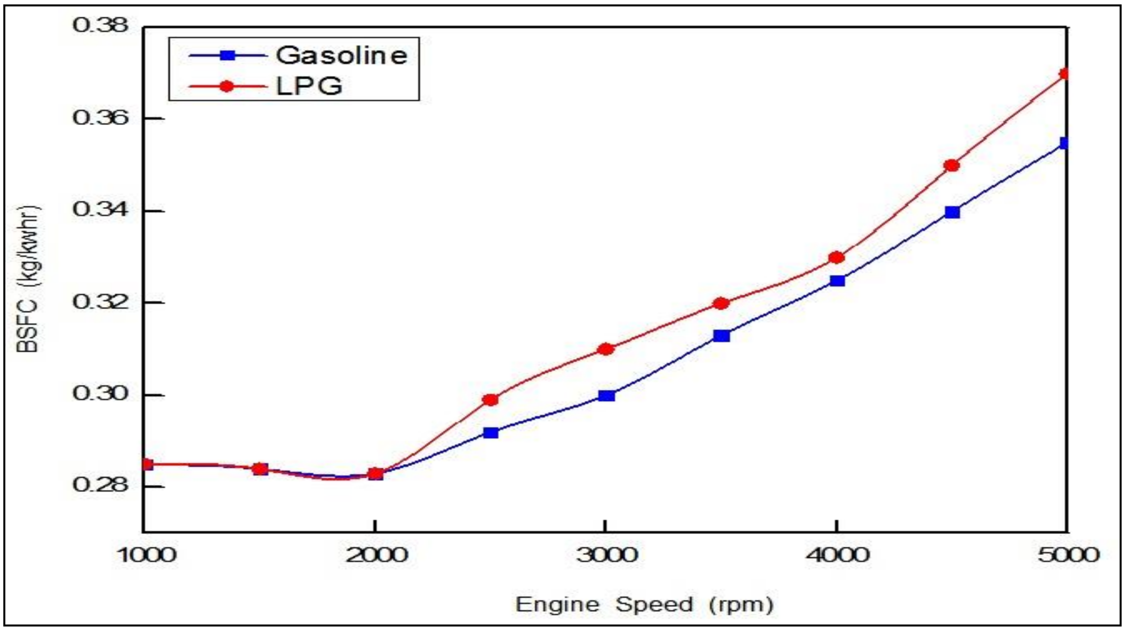

Fig. 6. *Graph Between BSFC and Engine Speed.*

Figure 6 illustrates the plot between BSFC and Engine Speed. The plot clearly shows the BSFC variation for both Gasoline and LPG. BSFC for LPG is more as compared to conventional fuel. The higher mass heating value of LPG and its positive effect on combustion efficiency are the most evident factors for this result. BSFC was typically increased for higher speeds. The reason behind BSFC increase is because number of working cycles is more for Specific period of time at higher engine speeds.

EMISSIONS

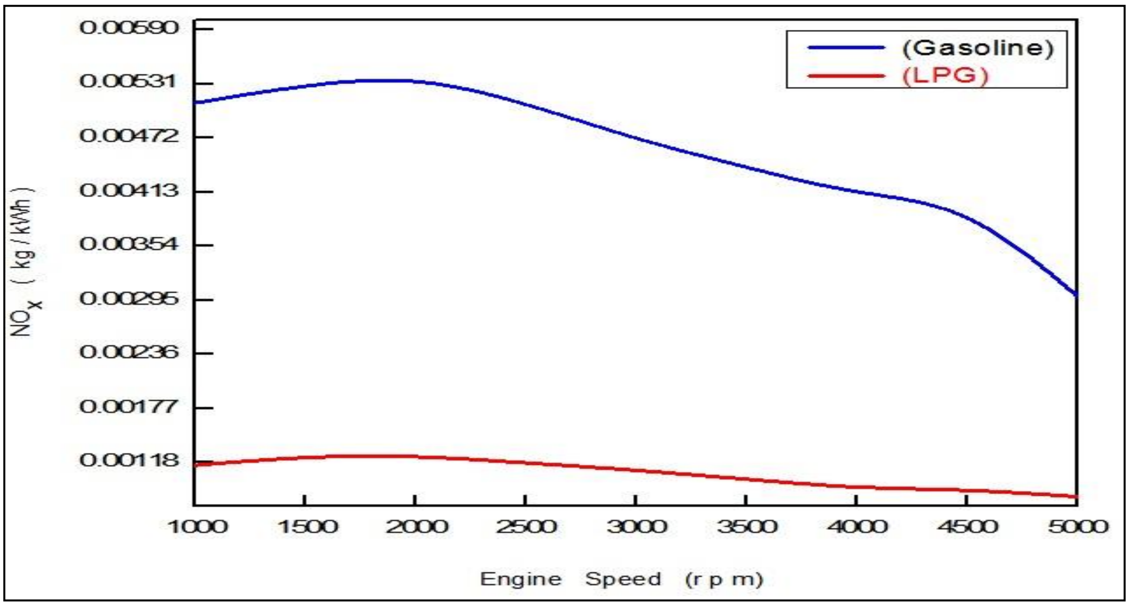

Fig. 7. *Graph Between NOx and Engine Speed.*

Figure 7 shows the plot between NOx and engine speed. The graph clearly shows the relation between NOx emissions of Gasoline and LPG. As NOx in case of

Gasoline is more as compared to LPG. In the above diagram it is clearly showing that at lower engine speeds the NOx is more at the start and decreasing at increasing speeds, because the NO*x* emission is largely affected by the excess air ratio and ignition timing.

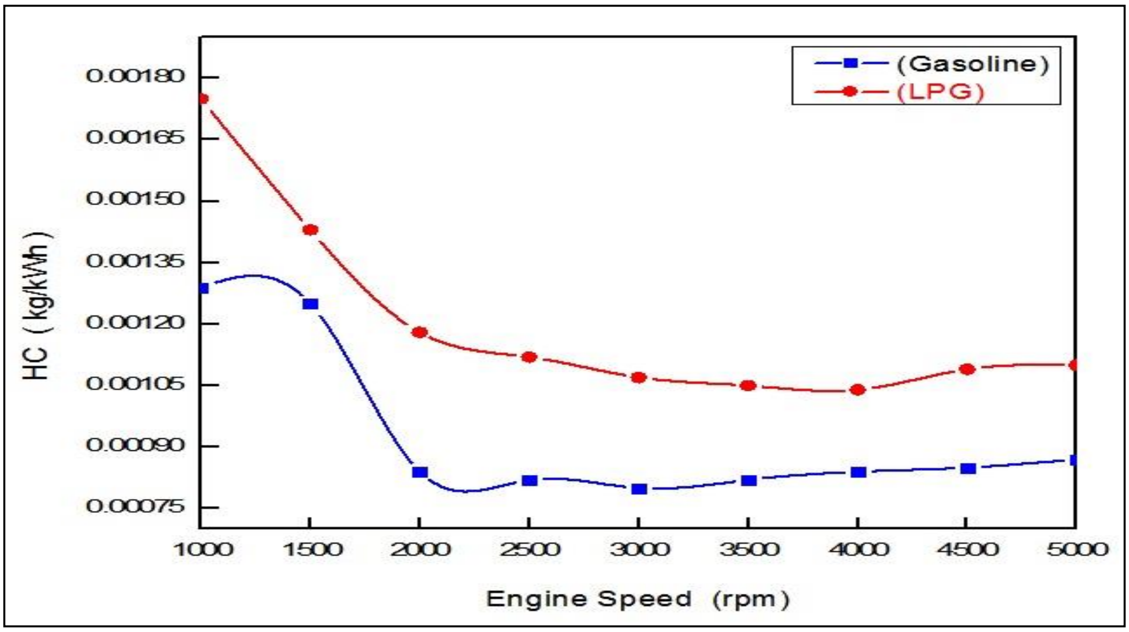

Fig. 8. *Graph Between HC and Engine Speed.*

Figure 8 shows the plot between HC emissions and Engine speed. Again the HC emission for LPG is more at the start for LPG and correspondingly decreasing with increase in engine speed for LPG. The reason behind it is that there is incomplete combustion, and it occurs when the Combustion Quality is poor.

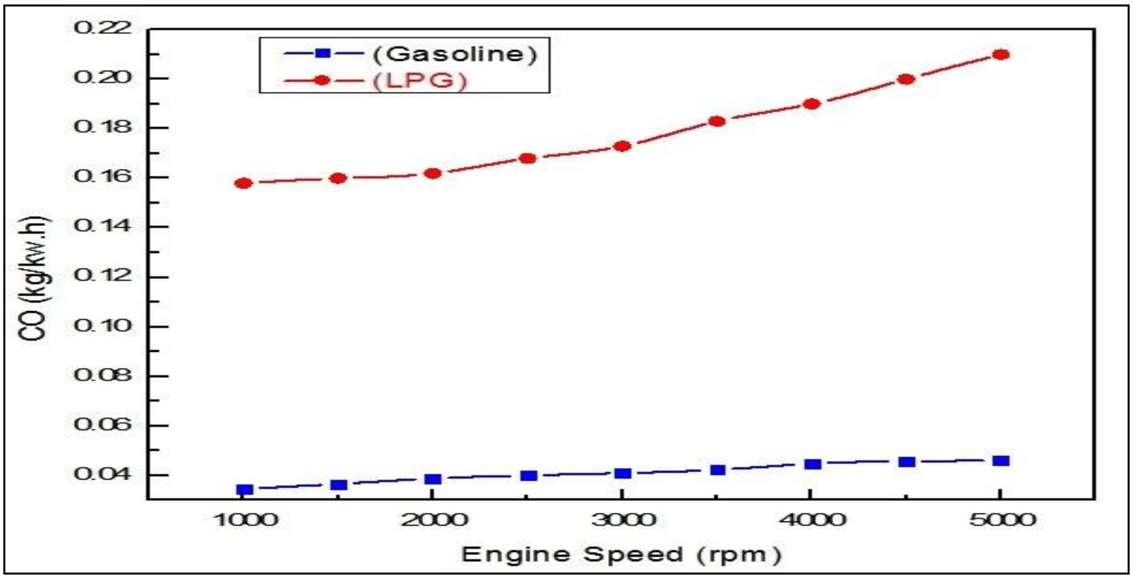

Fig. 9. *Graph Between CO and Engine Speed.*

Figure 9 shows the plot between the CO emissions and Engine speed. As the engine speed increases, the CO emissions for LPG increase. And it is less for Gasoline. This was believed to be caused by insufficient time for the oxidation of CO to CO_2

because of the shortened combustion duration under a higher pressure and temperature.

CONCLUSION

Simulations were carried out at varying engine speed and at 100% load conditions. The variations in Brake power, BSFC, and exhaust gasses were examined. Results obtained in this study were outlined below.

- A variable Engine Speed SI engine is made as global parameter in AVL boost software with the compression ratio capable of being varied from 6 to 12 for SI engine.
- The Simulation was conducted using two fuels namely Gasoline and LPG as dual fuel.
- The Power was shown an increase depending on the LPG usage. The brake power increased considerably with the use of Gasoline. As for the LPG usage, power increased in proportion to increasing engine Speed. BSFC increases with the increase in engine speed and the minimum BSFC value was obtained at minimum engine speed.

Positive results in terms of engine performance were only achieved at all percentage of LPG mixture ratio. With the use of mixture containing LPG, BSFC decreased with increase in Engine Speed.

Faster fuel evaporation*:* Improved fuel atomization leads to smaller droplets and a faster fuel evaporation. More uniform fuel distribution*:* For each cylinder the fuel is metered separately by the corresponding port fuel injector.

More rapid dynamic response to changes in throttle position and hence transient operation: Faster fuel evaporation leads to rapid mixture formation and fast dynamic response. Hence, less fuel enrichment is required during acceleration. More precise control of air-fuel ratio: Use of closed loop feedback control system that Employs exhaust oxygen sensor very precise control of air-fuel ratio is obtained so the unnecessary fuel enrichment of the engine can be prevented.

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