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"PERFORMANCE EVALUATION OF FOUR STROKE SI ENGINE BY DIRECT INJECTION OF LPG"

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Abstract

At a design and development stage an engineer would design an engine with certain aims in his mind. The aims may include the variables like indicated power, brake power, brake specific fuel consumption, exhaust emissions, cooling of engine, maintenance free operation etc. The other task of the development engineer is to reduce the cost and improve power output and reliability of an engine. In trying to achieve these goals he has to tries various design concepts.

The LPG has been suggested as a convenient, clean burning less pollutant fuel. LPG is among the many alternative Proposed to replace gasoline in the short term due to its excellent Performance characteristics as a fuel for spark ignition engines. Therefore it is also known as Green Fuel. The Brake powers, BSFC, Thermal efficiency, Air-fuel ratio, are some of the parameters that need to be analyzed and optimally exploited for better engine performance.

In the present paper a comprehensive review of various operating parameters and concerns have been prepared for better understanding of performance evaluation of direct injection system for a LPG fueled sparked ignition engine. Keeping this in mind, a model of a 4-stroke spark ignition engine was developed by direct injection of LPG with the help of nozzle which inject the LPG in suction stroke only. This paper is an attempt to compare petrol engine performance with the Direct Injection of LPG. It showed that the BSFC is reduced and the Thermal efficiency was slightly increased in.

Keywords – LPG fuel and system, Spark ignition engines, performance characteristics and direct Injector (nozzle), direct injection of LPG.

1. INTRODUCTION

1.1 Background

In design and development stage an engineer would design an engine with certain aims in his mind. The aims may include the variables like indicated power, brake power, brake specific fuel consumption, exhaust emissions, cooling of engine, maintenance free operation etc. The other task of the development engineer is to reduce the cost and improve power output and reliability of an engine. The nature and the type of the tests to be conducted depend upon various factors, some of which are: the degree of development of the particular design, the accuracy required, the funds available, the nature of the manufacturing company, and its design strategy.

The increasing cost gasoline and of liquid hydrocarbons in recent years accompanied by the tough rules and regulations regarding exhaust emissions has stimulated interest in alternative fuels for automotive engines. 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 the life of some components such as piston rings, bearings are much longer than with gasoline. The high octane of LPG also minimizes wear from engine knock. The octane number is high, which should improve engine efficiency. To achieve the demand of minimization of cyclic variations, liquefied petroleum gas (LPG) among the gaseous fuels can be used.

A stoichiometric LPG-fueled engine has limited application due to excessively high exhaust gas temperatures, which cause durability problems and a lower thermal efficiency. However, the lean burn strategy may also be implemented to overcome these shortcomings. Additionally, the level of engine modifications required to convert a conventional spark ignited (SI) engine to DI of LPG lean burn engine is low enough to make lean burn operation a cost-effective way to achieve better emissions and fuel efficiency LPG is an environmentally friendly fuel for spark ignition engine which has potential emission advantages over gasoline, LPG is liquefied under pressure and compressed and stored in steel tanks under pressure that varies from " [1.03 to 1.24 (MPa)]". It is used for heating, cooking, and can be used as engine fuel. The fuel is liberated from lighter hydrocarbon fraction produced during petroleum refining of crude oil and from heavier components of natural gas. It is also a by-product of oil or gas mining. Pollution presents a comprehensive review of LPG.

On the other hand, in semi injection LPG displaces 15–20% greater volume than gasoline. Thus the power output decreases by 5–10%. This reduction can reach up to 30% at very lean conditions the important thing is that it require very small change in existing SI engine there are many reports about the effects of the LPG on the engine performance.

1.2 Overview

Although the LPG is known as Green Fuel. However, the selection of an alternative fuel is not the end of the task. The selected fuel has to be exploited to its best Performances capacity to serve the task for which it was chosen. The fuel consumption can improve by optimizing the amount of heat generated in combustion chamber and surroundings. In direct injection of LPG, the LPG can be directly supply inside the combustion chamber so that it take less time for displace from Suction manifold to chamber and give good burning effects. As it has the octane number is high, which should improve engine efficiency. The LPG is directly injected inside the chamber by many ways Like at the time of end of compression stroke but, for that it require the ECU unit that is not a easy job that is why in this project LPG is directly injected inside the combustion chamber by the simple nozzle arrangement. LPG less volumetric efficiency than gasoline. Thus the power output increases by 5–10%. However, the important thing is that it requires very small change in existing SI engine there are many reports about the effects of the LPG on the engine performance.

1.3 LPG as fuel

The LPG has less carbon percentage than gasoline therefore; LPG has been suggested as a convenient clean burning less pollutant fuel. Hence it is also known as Green Fuel. Since LPG burns cleaner with less carbon build-up, oil contamination, engine wear is reduced and the life of some components such as piston rings, bearings are much longer than with gasoline. The high octane of LPG also minimizes wear from engine knock. The octane number is high, which should improve engine efficiency.

1.3.1 LPG Characteristics and its properties comparison with gasoline

As LPG is the by-product of gasoline it has different properties than gasoline it has chemical formula C3H8 and for gasoline has C8H18 which shown that LPG having less carbon than gasoline and having anti knocking properties means high octane number i.e. 105+.

Table1.1 the properties of LPG in comparison with gasoline.

Properties/fuels	Gasoline	LPG
Chemical structure	C_8H_{18}	C_3H_8
Octane number	86-94	105+
Lower heating value (MJ/Kg)	43.44	46.6
High Heating Value (MJ/Kg)	46.53	50.15
Stoichiometric air/fuel ratio	14.7	15.5
Density at 15˚C ,kg/m^3	737	1.85/505
Specific Gravity 60° F/60°	0.72-0.78	0.85

The advantages and drawback of LPG

Advantages are as follows.

- Because LPG vaporizes when released from the tank and is not water soluble, LPG does not pollute underground water sources.
- Power, acceleration, payload and cruise speed are comparable to those of an equivalent vehicle fueled on gasoline.
- LPG has a high octane rating of 104, in-between Compressed Natural Gas (CNG) (130) and regular unleaded gasoline (87).

- Refuelling a LPG vehicle is similar to filling a gas grill tank; the time it takes is comparable with that needed to fill a CNG, gasoline or petrol fuel tank.

- Its high octane rating enables it to mix better with air and to burn more completely than does gasoline, generating less carbon. With less carbon build up, spark plugs often last longer and oil changes are needed less frequently.

- Because it burns in the engine in the gaseous phase, LPG results in less corrosion and engine wear than does gasoline.
- Clean emissions in vehicles - environmentally friendlier to use in public areas.
- No reduction in performance - power outputs do not change in vehicles.

Drawbacks are as follows:

- In cold conditions, below "[32 degrees Fahrenheit]", starting could be a problem because of the low vapor pressure of LPG at low temperatures.

- One gallon of LPG contains less energy than a gallon of gasoline. The driving range of a LPG vehicle is about 14% lower than a comparable gasoline-powered vehicle.

- LPG is generally higher priced than other fuel alternatives such as CNG and gasoline.

- There are over 4,000 LPG refueling sites in the US, more than all of the other alternative fuels combined. Most of these stations, however, are not readily available to consumers on a 24/7 basis. This is one of the reasons why most on-road applications are bi-fuel vehicles, which burn LPG and gasoline.

2. OBJECTIVES

2.1 Concluded objectives

From studied above literature review it can be concluded that the LPG is the best alternative fuel as it is easy to transport and though it may be give some little damages on long term but as concern with fuel economy and performance it is best suited fuel.

The concluded objectives of this project are:

- To understand the performance parameters in evaluation of SI engine performance.
- To identify Benefits of direct injection.
- To modify existing engine for D.I of LPG.
- To compare the DI of LPG with petrol at same operating condition on same engine.

3. CONVENTIONAL FUEL SUPPLY SYSTEM

3. 1Carburetion

The term carburetion covers the whole process of applying continuously to a petrol engine mixture of vaporised fuel and air which is suitable to each engine condition of load, speed, and temperature. The function of the carburettor is to measure out the correct proportions of liquid fuel and air for the particular engine condition. The liquid fuel must be atomized at the carburetor (i.e. broken up into a fine spray to assist in the evaporation of the fuel, so that the mixture entering the cylinders is homogeneous). The fuel leaves the Carburetor and travels through the manifold in three forms: as vapor; as liquid droplets suspended in the air stream; as a liquid film on the manifold wall. As the work of an engine is directly dependent on the mass of air inducted, for this reason complete vaporization of the fuel in the manifold is not desired since the vaporized fuel would displace air.

On the other hand, too little vaporization in the manifold may lead to poor distribution of the fuel from cylinder to cylinder

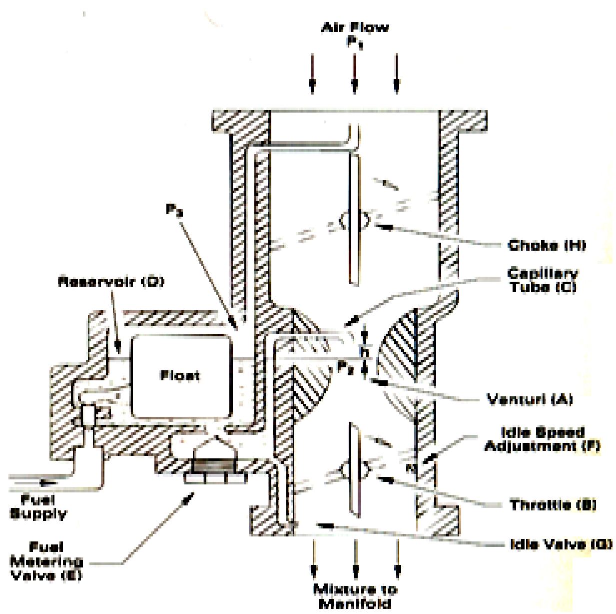

Figure 3.1 The Carburetor

3. 2 Deficiencies of carburetor

The pressure drop in carburetor due to restriction in the flow passage impairs the volumetric efficiency. In multi cylinder engines the charge supplied to various cylinders varies in quality and quantity. Different carburetor auxiliaries fitted to the carburetors made it a complex device. Problem of carburetor icing. In accurate fuel metering during cornering, and tilted position.

3.3 History of electronic fuel injection

Automakers found that the traditional engine control could not control the engine sufficiently to meet emission limits and maintain adequate engine performance at the same time. In 1970s, electronic control systems in vehicular engine were introduced. The motivation for electronic engine control came from two main requirements: stringent exhaust emission legislation and thrust to improve average fuel economy.

Past trends of vehicle design were: more power and bigger size; little or no concern on fuel efficiency and exhaust emission. Present trends and needs are: fuel efficiency and smaller size; emission consideration; yet smooth and reliable operation.

3.4 Advantages of electronic fuel injection.

Improved atomization (fuel is forced into intake manifold under pressure which helps break fuel droplets into a fine mist); smoother idle (lean fuel mixture can be used without rough idle because of better fuel distribution and low speed atomization); improved fuel economy (high efficiency because of more precise fuel metering, atomization and distribution; lower emissions (more accurate and efficient air-fuel mixture reduces exhaust pollution); better fuel distribution; better cold weather drivability (injection provides better control of mixture enrichment than a carburetor choke); increased engine power (precise metering of fuel to each cylinder and increased air flow can result in more power); elimination of carburetor plate icing.

3.5 Classification of EFI

An EFI System can be divided in to four sub systems: fuel delivery system; air induction system; sensor systems; computer control system.

A: With respect to number of injection point: Single-Point or Throttle-Body Injection (SPI or TBI); Multipoint Injection (MPFI).

B: With respect to place of injection: Direct Injection; Indirect Injection.

C: With respect to injection control: Electronic Fuel Injection; Hydraulic Fuel Injection; Mechanical Fuel Injection.

4. EXPERIMENTAL SETUP

4.1 Introduction to Engine Set Up

The following experimental work will conducted to evaluate and examine the direct use of LPG in a small internal combustion engine in terms of the engine performance. For this we use Engine of Bajaj "[92.2cc]" single cylinder, air-cooled motorcycle engine produced by Bajaj Safire

4.2 Engine specification

In this project work, the experiments were performed on a "[92.2cc]" single cylinder, air-cooled motorcycle engine produced by Bajaj Safire Detailed specifications of the test engine are shown in Table 4.1

Here in this we are injected the LPG directly inside the chamber for these it is necessary to inject it in proper proportion which is achieved by injecting the LPG through nozzle which in just like NRV non return valve.

TABLE NO. 4.1 SPECIFICATION OF AVAILABLE ENGINE

Displacement	92.2 cc
Bore* stroke	50mm*56.9mm
Power	7.4bhp(5.4kw)
Torque	7.85Nm
Engine type	Bajaj Safire
Cooling system	Air cooled
RPM	5800
Stroke	4
No. of cylinder	Single

4.3 Engine Setup

The experimental setup for Engine testing is shown in Fig 4.8. For the engine test, Rope brake dynamometer is employed to measure the engine output torque and speed. LPG flow was measured by electronic weight digital indicator.

4.4 Modification in Experimental Setup

While performing experimental work we have to modify the engine set as per our requirement. Since it had to be altered for using gaseous fuels such as methane and LPG. Here in this we are injected the LPG directly inside the chamber for these it is necessary to inject it in proper proportion which is achieved by injecting the LPG through nozzle which in just like NRV non return valve.

4.5 Engine modification

The engine's original fueling system is configured for liquid gasoline. Hence, it had to be altered for using gaseous fuels such as methane and LPG. The following parts of the engine were removed or modified. Carburetor, fuel tank, and fuel pump. Engine is drill with proper size of nozzle bush and fit it inside the combustion chamber at the opposite of spark plug.

4.6 Microprocessor unit (MPU)

MPU is failure because we got only 5 to 6 time per sec but we want 46 injections per sec.

The Engine RPM are 5800

For Convert in RPS 5800/60 = "[96.66 RPS]"

No. of stroke = 4 No. of revolution = 2

Therefore, 96.66/2 . ………………… (N/2)

We want 46 time injection per sec , But it gives injection 5 to 6 times per sec.

As we want the injection for injecting fuel when piston start move from BDC to TDC. Just before power stroke at least 46 times /sec but we get it "[5-6 times /sec]" hence it was failure.

Figure 4.1 MPU Microprocessor unit

4.7 Nozzle Injector.

Conversion of SI petrol to LPG engine we manufacture a nozzle that is just like one way valve.

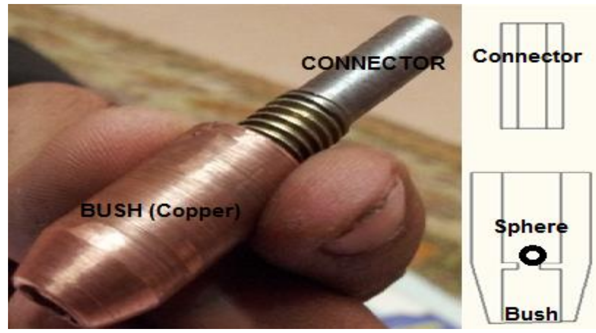

Figure 4.2 Nozzle for injecting LPG in combustion chamber.

4.8 Nozzle for Injecting LPG in Combustion Chamber

Conversion of SI petrol to LPG engine we manufacture a nozzle that is just like one way valve. As told earlier we haven't got the proper injection therefore we made another provision for injecting the fuel inside the chamber directly at time of suction in place of at the time of power stroke. We inject it during the suction stroke with the help of injector which is one way valve type injector it allow the LPG to flow inside the chamber due to creation of –ve pressure inside the combustion chamber and restricts the reveres flow at the time of other 3 stroke during Compression, Expansion, and Exhaust.

As it should not flow reserves because in compression and power stroke there is maximum pressure and temperature nearly "[22bar]" and "[500-600oc]" created inside the chamber so it may risk of explosion to avoided this and for safe operations we used the Flashed back arrested.

4.9 Nozzle fitted in the chamber (Head Block)

The nozzle is to be fitted with fixing agent adhesive past whereas it should be tap because if it is not properly fixed then it may be displace or leakage which cause problem to create sufficient compression.

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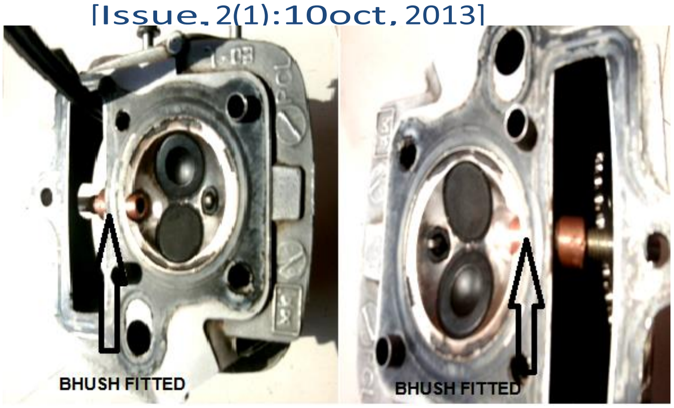

Figure 4.5 After fitting the nozzle inside the chamber

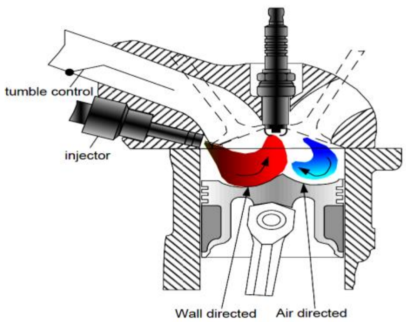

Figure 4.6 Line diagram of modification

Figure 4.7 Injector actual position on working model as direct injection.

4.10 Actual working setup

The experimental set up on which the performance had carried out was given in the figure 4.8. It consists of measuring unit, LPG cylinder, engine, weight measuring machine and nozzle for DI injection.

Figure 4.8 Actual working setup

4.11Sample Calculations Steps

The calculation for performance is given below.

Engine efficiency (ηf): The engine efficiency is defined as the ratio of engine power output to the heat release Rate of the fuel, as follows:

Engine efficiency

$(\eta f) = BP / (Mf \times CV)$ ………………. Eq. (1)

Is the heating value of the fuel "[MJ/kg of fuel]" 3600 is a conversion factor.

Brake Specific fuel consumption: it is the ratio of mass of fuel supplied to break power.

Defined as it is the mass flow rate of fuel "[g/hr]", and P is the engine power output "[kW]". Thus, the Unit of BSFC is "[g/kWh]". A lower BSFC value indicates a lower fuel consumption rate under the same engine power output and higher engine efficiency, implying better fuel economy.

Brake Specific fuel consumption,

$BSFC = Mf / B.P$ ………………. Eq. (2)

Volumetric Efficiency: Volumetric efficiency is ratio of volume of air supplied to sweep volume.

Volumetric efficiency

$(\eta fVol) = Va / Vs$ ………………. Eq. (3)

4.12Procedure for petrol

- Start the engine and maintained the constant speed.
- Take RPM reading by tachometer

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- Take time for 10cc of fuel is measure.
- Take manometer reading for air flow.
- Vary load and maintain speed of previous RPM.
- Repeat same for "[300,400,500 rpm]", at load "[0,2,4,6. Kg]".

4.13 Procedure for LPG

- The same producer is to be followed for calculation of LPG reading at variable load and constant RPM.
- Electronic weight balance is to be used for measurement flow rate LPG simultaneously with the help of stopwatch which gives reading for time.

4.14 Difficulty

- It was very difficult to drill in head of combustion chamber because in 4 stroke SI engine there is the valve mechanism and timing chain which cause less approach for drilling at perfect location and inclination.
- Made up of appropriate E.C.U.is not easy for as the setup used was single cylinder therefore, it was difficult to made it there working principal was depend on the position of sensor. It is very difficult to make the separate ECU system for the single cylinder and as it is not available in market. In its most basic form, only 2 kinds of sensors are absolutely required to electronically control a fuel injected, spark-ignition engine.

- Load Indication (MAP, TPS, MAF)

Figure 4.9 Electronic control unit load indication

- Engine Position/Speed (Crank or Cam)

However, limiting the inputs severely hinders the control system's ability to perform at a high level.

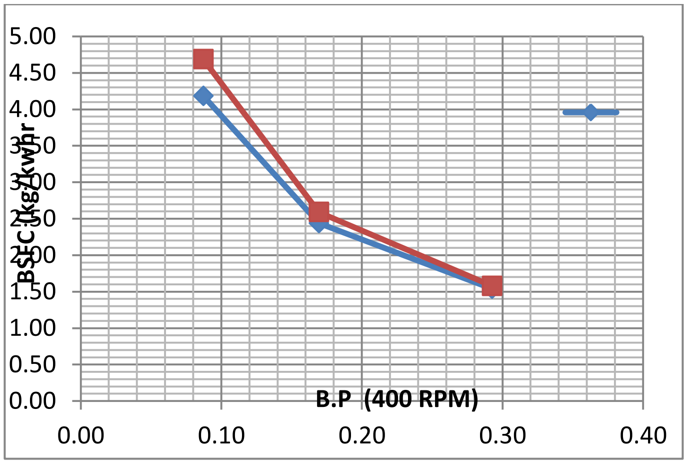
Figure 4.10 Electronic control unit engine position/speed (crank or cam)

- so we tried to make MPU which is failure because we got only "[5 to 6 time per sec]" but for proper working of engine we want 46 times injections per sec.
- Spark plug is damage after continuous running of engine. Because it exactly in front of LPG nozzle. The maintain of proper isometric ratio for gas is difficult.

5. RESULTS AND DISCUSSION

5.1 B.P vs BSFC (At 400 RPM and Variable Load)

This graph is plotted for 400 RPM at variables (0,2,4,6) where the blue line indicate petrol and red line LPG Variations this is plotted against brake power vs. brake specific fuel consumptions.



Graphs 5.1 B.P Vs BSFC (At 400 RPM and Variable Load)

Graph 5.1 indicate that the mass of fuel consumption of LPG gradually increasing with respective to increasing the Brake Power.

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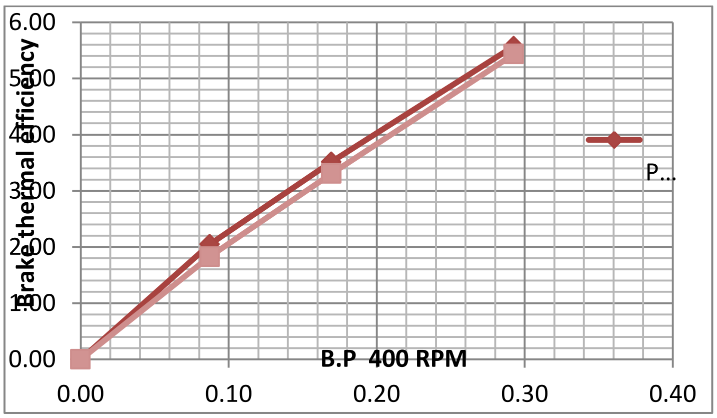
It indicate that the mass of fuel consumption of LPG gradually decrease w.r.t. increasing the Brake Power, initially LPG has slightly high mass of fuel consumption of the engine in comparison with petrol. But with increasing load and RPM LPG has the mass of fuel consumption values slightly lower than the using gasoline-fuel.

5.2 Brake thermal efficiency vs B.P (At 400 RPM and Variable Load)

This graph is plotted for 400 RPM at variables (0,2,4,6) where the blue line indicate petrol and red line LPG Variations this is plotted against brake thermal efficiency vs. brake power.



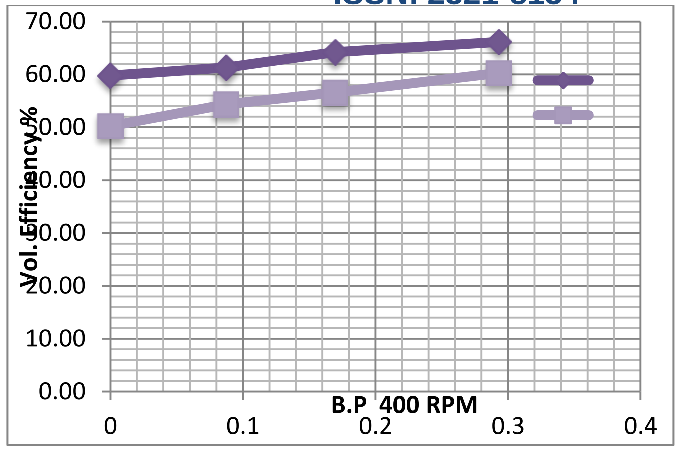
Graphs 5.2 Brake thermal efficiency. Vs B.P (At 400 RPM and Variable Load)

Above graph shows brake thermal Efficiency of the engine is gradually increasing w.r.t. increasing the Power.

However, the Brake Thermal efficiency increases when the Load and RPM increases. When using LPG fuel the Efficiency values slightly higher than the using Gasoline fuel.

5.3 Volumetric efficiency vs. B.P (At 400 RPM and Variable Load)

This graph is plotted for 400 RPM at variables (0,2,4,6) where the blue line indicate petrol and red line LPG Variations this is plotted against Volumetric efficiency vs. brake power..



Graphs 5.3 Volumetric efficiency Vs B.P (At 400 RPM and Variable Load)

As shown in graph with at the low BP the LPG has volumetric efficiency high whereas it will reduce with increasing the BP. comparison with petrol, LPG has less volumetric efficiency. It slightly increased with load B.P

6. CONCLUSIONS AND FUTURE SCOPE

6.1 Conclusions

It found that as load and RPM (B.P) increases break thermal efficiency also increases. Because LPG has a higher calorific value with octane rating (105+).

At starting the gasoline having lower BSFC but as load increases BSFC of LPG reduce. Because the C.V of Gasoline is “[43MJ/Kg]” less compared to the LPG “[46.1MJ/Kg]” and it is in gaseous from therefore the burning rate of fuel is increased, and thus, the BSFC is decreased.

Using LPG the mass of fuel consumption values is lower than the using gasoline fuel.

The burning rate of fuel is increased, and thus, the combustion duration is decreased. Therefore, the cylinder pressures and temperatures for LPG are higher compared to gasoline.

6.2 Future Scope

The above set up will study by using Liquefied Petroleum Gas (LPG) at Constant speed and variable load on the single cylinder four stroke spark-ignition engines.

The same set up will be study for compare Gasoline and LPG – Gasoline blends "25%, 50%, and 75% of LPG in Gasoline.]" at various Speed and Constant load of the engine.

If E.C.U. unit will available the DI of LPG can be inject during the power stroke when piston start move from BDC to TDC means just before the end of compression.

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