PERFORMANCE EVALUATION OF A DIESEL ENGINE RUNNING IN DUAL FUEL MODE WITH KARANJA BIO DIESEL (KOME) & LIQUIFIED PETROLEUM GAS (LPG)

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ABSTRACT

Present study shows utilisation of LPG in CI engine with Bio diesel in dual fuel mode. For this experimental work a stationary, single cylinder, four stroke diesel engine was used with few attachments. Major performance parameters such as Brake power, Brake thermal efficiency, Brake specific fuel consumption etc. were evaluated at different loads and with different fuel combinations. up to 12% biodiesel was saved in dual fuel mode & up to 40% improvements were evident in Brake specific fuel consumption, whereas break thermal efficiency did not improve due to poor utilization of high energy content of LPG. The cost incurred for making Biodiesel was huge and disappointing but if it is promoted by government and made on a large scale, it would definitely prove itself as an affordable fuel. The concept of present work of mixing biodiesel and LPG for operating diesel engine can be employed to make more technologically subtle & advance engines that could run smoothly on dual fuel and harness their full potential.

Key words: C.I. Engine; Biodiesel; Karanja Oil Methyl Ester; Dual Fuel Etc.
1. INTRODUCTION

In today’s scenario, the most challenging global issues are Energy security and Environmental concerns caused due to burning of Fossil fuels. Today, the whole world relies heavily on Fossil fuel reserves which are limited and depleting rapidly. Global oil supplies may peak in the next few decades and oil prices could rise dramatically. Significantly higher energy prices would adversely affect economic growth and complicate poverty reduction efforts in developing countries like India. \(^{(1)}\) Research are going all over the world for finding a suitable, sustainable, non-polluting and renewable source of energy which can fulfill the energy demand of the world. Bio-fuels have come up as a promising alternative and intensive research are going on for more refined bio fuels having higher calorific value, lesser harmful emissions and smoother running engines. Several research are being carried on for finding suitable mixes of bio fuels, bio fuels with other fuels such gas CNG, LPG, Bio gas etc. to replace their lower calorific value deficiency. The Bio fuels may be considered green as the emission produced by them is filtered during their lifecycle. Bio fuels offer an attractive option for meeting part of India’s energy needs. Bio fuels, in theory, can be produced from a wide variety of domestic feedstock. Like solar or wind power, bio fuels are considered renewable energy sources as they rely on plant or waste products. This paper deals with biodiesel & LPG, a subset of bio fuels along with a Fossil gas that can substitute for petroleum diesel. Many universities across the world are running research programs in the field of renewable energy to promote and fight the coming up energy scarcity of the world. Bio fuels are affordable substitutes for imported fossil fuels, generate rural income and employment, and reduce GHG emissions. But they also compete for agricultural resources, and this competition may seriously undermine food security. For India, with its growing population and fixed amount of arable lands, food security is a prime concern. India’s bio fuels policy clearly states that energy crop production should not be promoted at the cost of the food sector. Biodiesel produced from non edible oilseeds cultivated on wasteland or fallow land gives India an opportunity to enhance its energy security without compromising food security.

In this paper, we are using a non edible oil (Pongamia Pinnata oil) made biodiesel along with the LPG to run a conventional Diesel engine with few modifications. India relies heavily on imported oil to fuel its rapidly growing economy. The country’s reserves of fossil fuels are limited. Petroleum imports in the last few years ran nearly four times domestic production. \(^{(2)}\) This dependency is likely to increase. India’s per capita energy consumption was roughly one-quarter of the global average, a figure that will only increase with a rising standard of living. \(^{(3)}\) This leaves the country vulnerable to price shocks when oil prices rise on global markets.

Biodiesel production in India is a special case which has much more positive development effects than biodiesel production elsewhere. India is different because there is far-reaching consensus there that biodiesel production will only be promoted on the basis of non-edible oil seeds on marginal lands. Hence the risks of driving up...
Performance Evaluation of A Diesel Engine Running In Dual Fuel Mode with Karanja Bio Diesel (Kome) & Liquified Petroleum Gas (LPG)

prices for edible oil or crowding out food production are relatively low. In addition, cultivating tree-borne oilseeds on degraded lands stabilizes soils and creates carbon sinks, and production requires low inputs, which serves to further improve the carbon balance.

Methods for converting a diesel engine to consume alternative fuels typically fall into three categories. The first is to convert the engine to a spark-ignited engine; a second is to convert the engine to allow for the direct injection of gaseous-fuels into the combustion chamber; and a third is "fogging" or "fumigation" of the gaseous-fuel with all or a portion of the intake air charge entering the engine.

In our experiment, we will be using this method of fumigation to run the governor controlled constant speed diesel engine in dual fuel mode using Karanja Bio Diesel and LPG. In this method, the mixture of gaseous-fuel with the intake air charge is introduced into each cylinder of the engine during the intake stroke. During the compression stroke of the piston, the pressure and temperature of the mixture are increased in the conventional manner. Near the end of the compression stroke, a smaller than normal quantity of diesel fuel from the engine's existing diesel fuel injection system is injected into the cylinder. The diesel ignites due to compression and in turn ignites the mixture of gaseous-fuel and intake air, which in turn, accelerates the flame front of the Diesel Fuel, enhancing the combustion process. For the purpose, we have attached a convergent divergent steel nozzle in the path of air supply to combustion chamber and made a very small hole at the throat of nozzle to accommodate the gas welding torch tip for supplying LPG during operating the engine. The supply of LPG has been kept constant, only the Load on the engine has been changed and performances were observed. Bio-Diesel poses to be a promising fuel for future and mixing LPG with it gives it the desired power which seems to be lacking with biodiesel alone, also the LPG helps to burn the fuel completely and therefore reduces emissions and helps to harness the overall energy contained in the fuel. Furthermore, engines using such fumigation systems may typically be operated in a dual-fuel mode or in a strictly diesel mode (e.g., when gaseous-fuel is not available).

Table 1 Comparison between properties of Karanja biodiesel and LPG:-

<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>KOME BIODIESEL (8)</th>
<th>LPG (6,7)</th>
<th>DIESEL (5,8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal State</td>
<td>LIQUID</td>
<td>GASEOUS</td>
<td>LIQUID</td>
</tr>
<tr>
<td>Calorific Value(Kj/Kg)</td>
<td>37580</td>
<td>LHV: 46350</td>
<td>LHV: 43400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HHV: 50350</td>
<td>HHV: 44800</td>
</tr>
<tr>
<td>Density(Kg/M³)</td>
<td>891.8</td>
<td>525-580(liquid)</td>
<td>820-950</td>
</tr>
<tr>
<td>Specific Gravity(Relative To Water)</td>
<td>0.891</td>
<td>0.525-0.580(liquid)</td>
<td>0.82-0.95</td>
</tr>
<tr>
<td>Flash Point(°C)</td>
<td>136</td>
<td>-104</td>
<td>62</td>
</tr>
<tr>
<td>KINEMATIC VISCOSITY, Cst</td>
<td>5.5</td>
<td>---</td>
<td>2.4</td>
</tr>
<tr>
<td>Fire Point(°C)</td>
<td>223</td>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Auto Ignition Temperature(°C)</td>
<td>---</td>
<td>-410-580</td>
<td>176.4 TO 329.44</td>
</tr>
<tr>
<td>Cetane Number</td>
<td>05-10</td>
<td></td>
<td>40-60</td>
</tr>
<tr>
<td>Stichiometric A/F Ratio (Mass)</td>
<td>--</td>
<td>15.7</td>
<td>14.5</td>
</tr>
<tr>
<td>Peak Flame Temperature(°C)</td>
<td>--</td>
<td>1990</td>
<td>2054</td>
</tr>
<tr>
<td>Boiling Point(°C)</td>
<td>-42</td>
<td></td>
<td>149-371</td>
</tr>
</tbody>
</table>
It is clear from the table that LPG has a quite low Cetane number which makes it inefficient for self ignition, that’s why a small quantity of Bio Diesel known as pilot fuel is to be supplied to provoke ignition in the combustion chamber. The rest of power is supplied by the combustion of LPG. And since LPG has a greater Calorific value, its combustion facilitates in providing required or greater power consuming a lesser quantity of fuel thus improving the fuel economy.

With Dual Fuel operation, there is no change to the basic architecture of the diesel engine – or to the principle of diesel combustion. The engine itself is virtually unaltered, but for the addition of a gas injection system. The Dual-Fuel in-cylinder temperatures and pressures remain within the limits of pure diesel operation, so the converted engine operates within the parameters of the original engine. In a Dual-Fuel engine, however, the diesel fuel injector works like a liquid spark plug. Highly pressurized, it ignites a mixture of compressed gas and air in the cylinder.

2. SPECIFICATIONS OF THE TEST ENGINE

The engine used in this experiment is installed at University Institute of Technology, Rajiv Gandhi Technical University, Bhopal. The RGPV engine test contains a complete system for measuring all the parameters relating to the diesel engine performance analysis. The experimental set-up contains mainly a dynamometer to load the engine. Figure below gives a diagram of the experimental system used.

![Figure 1 Diesel Engine Test Rig Showing Dynamometer](image-url)
In order to convert the conventional diesel engine into a Dual-Fuel engine, we attached an Inspirator, an LPG fuel injector along with a flow controller to send LPG in a controlled way. For measuring the LPG flow we attached a Hot Wire Anemometer which measures the velocity of LPG in the delivery pipe and when this velocity is multiplied with area of cross section of Pipe, we get the volume flow rate.

### Figure 2 Diesel Engine Test Rig Showing Fuel consumption Meter, Temp. Indicator Etc

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Company and Model</td>
<td>Kirloskar Oil Engine, SV1</td>
</tr>
<tr>
<td>Type</td>
<td>Vertical, Totally Enclosed, Compression Ignition, Four Stroke Engine,</td>
</tr>
<tr>
<td>Cooling System</td>
<td>Water Cooled</td>
</tr>
<tr>
<td>Cylinder Number</td>
<td>Single cylinder</td>
</tr>
<tr>
<td>Bore</td>
<td>87.5 mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>110 mm</td>
</tr>
<tr>
<td>Swept volume</td>
<td>662 CC</td>
</tr>
<tr>
<td>Compression Ratio (R)</td>
<td>16.5:1</td>
</tr>
<tr>
<td>Rated Power (P) (kW)</td>
<td>8 HP</td>
</tr>
<tr>
<td>Nominal Revolution</td>
<td>1500 RPM</td>
</tr>
</tbody>
</table>
of LPG which can be further converted into mass flow rate by multiplying it to the Density of LPG.

For measuring the performance parameters, other devices such as Fuel consumption meter, belt dynamometer, thermocouples, rotameters etc are already attached with the engine test rig. In addition to this, we have supported the engine base with hard rubber dampers to reduce the vibrations. A water tank is used as a reservoir for the cooling of engine and exhaust calorimeter.

![Figure 3 Inspirator Setup For LPG Introduction](image1)

**Figure 3** Inspirator Setup For LPG Introduction

![Figure 3 Hot Wire Anemometer For Measuring Velocity of LPG Supply](image2)

**Figure 3** Hot Wire Anemometer For Measuring Velocity of LPG Supply
3. LPG KIT

We have used a 3 kg gas capacity LPG gas cylinder for the experiment. The gas is supplied through a PVC hose pipe, which hosts a Gas welding torch nozzle at the other end for producing a jet of LPG gas.

4. HOT WIRE ANEMOMETER

A Hot Wire Anemometer is inserted in the PVC pipe between the cylinder and engine to measure the velocity of the gas in the pipe. The velocity obtained is later used for measuring the volume flow rate or mass flow rate for measuring the performance parameters.

The volume flow rate is given by

\[ Q = v \cdot A \]

where:

- \( v \) = Flow Velocity
- \( A \) = Cross-Sectional vector Area/surface

5. INSPIRATOR

An Inspirator is a device, similar to Venturi tube and an Orifice plate, which mixes a fuel gas with atmospheric air in a precise ratio to regulate burn characteristics. Only the pressure of the fuel gas is used to draw in and mix the air. They are the most simple and common type of mixing device. Commonly used in gas stoves and furnaces. Burners using an inspirator are considered to be naturally aspirated.

In an inspirator there are 2 tubes. The first is a fuel gas pipe with an Orifice at the end where the gas comes out. Then in front of this there is another section of tubing with a larger diameter that the gas blows into. Usually (but not always) this second piece of tubing is tapered so that it starts getting narrower downstream from the orifice. Then, at a certain point, it stops getting narrower and either straightens out or starts getting larger again. This gives the fuel and air time to mix. The fuel/air ratio is determined by the ratio of the diameter of the orifice to the diameter of the mixing tube. In our experiment, we have used a gas welding torch nozzle of hole diameter of 0.1 mm as an orifice to supply fuel gas to engine. It supplies gaseous fuel at the throat of Venturi or Inspirator after which the diameter of Venturi starts increasing and gaseous fuel and air mix homogeneously and burn completely and give their full power to engine for running minimizing the quantity of liquid fuel to be used by the engine for producing the required power at that speed and load.
6. BIODIESEL REACTOR

Figure 4 Biodiesel Reactor At Biochemistry Lab In UIT, RGPV.

As mentioned above biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste oils and micro algae. There are three basic routes to biodiesel production from oils and fats:

- Base catalyzed transesterification of the oil.
- Direct acid catalyzed transesterification of the oil.
- Conversion of the oil to its fatty acids and then to biodiesel.

Almost all biodiesel is produced using base catalyzed transesterification as it is the most economical process requiring only low temperatures and pressures and producing a 98% conversion yield. For this reason only this process will be described in this report.

The Transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerine molecule as its base with three long chain fatty acids attached. The characteristics of the fat are determined by the nature of the fatty acids attached to the glycerine. The nature of the fatty acids can in turn affect the characteristics of the biodiesel. During the transesterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel and crude glycerol. In most production methanol or ethanol is the alcohol used (methanol produces methyl esters, ethanol produces ethyl esters) and is base catalysed by either potassium or sodium hydroxide. Potassium hydroxide has been found to be more suitable for the ethyl ester biodiesel production, either base can be used for the methyl ester. A common product of the transesterification process is Karanja oil Methyl Ester (KOME) produced from raw Karanja oil reacted with methanol.

The figure below shows the chemical process for methyl ester biodiesel. The reaction between the fat or oil and the alcohol is a reversible reaction and so the alcohol must be added in excess to drive the reaction towards the right and ensure complete conversion.
Figure 5 The products of the reaction are the biodiesel itself and glycerol.

To use in the experiment, the biodiesel was made from the neat Karanja oil purchased from local market at Bhopal, M.P. for the preparation of biodiesel, 5ltr. Neat Karanja oil was mixed with 1 ltr. Methanol and 72gms. Of dry KOH.

At first the neat Karanja oil was preheated at 60°C for 30 minutes and then methanol and KOH were added and mixture was heated for 2 hours and was continuously stirred with the help of a magnetic stirrer. After 2 hours, the reactor was shut down and biodiesel got prepared, it was left overnight for cooling in the reactor itself. The biodiesel was drained and collected in a 5 ltr. Container. After that, the sediment impurities of the made biodiesel are removed by a Separating funnel after which the biodiesel is ready to use in the engine for operation. The properties of the biodiesel are mentioned in table 1.

7. RESEARCH METHODOLOGY

In our work, we are mixing LPG with the Biodiesel by fumigation method to run the Engine and will be examining the effect on Performance for determining the suitability of Fuel-mix and compare it with neat diesel and neat KOME biodiesel.

As discussed earlier, we are using Diesel, KOME biodiesel & the Bio Diesel-LPG fuel mix to run our engine and LPG is been mixed by Fumigation technique. As our engine is governor controlled, it takes the bio Diesel fuel in accordance with its need. We provide LPG in a controlled way with the help of a Flow meter in different concentrations with help of a control valve and hot wire anemometer and observe the biodiesel fuel consumption in every step. We observe performance parameters in every case & try to determine suitability of biodiesel-LPG mix.

At first we start the engine and switch on every accessory such as water supply, temperature indicators and let the engine run for 20 minutes so that it can achieve its steady state. In the first set we run the engine on pure diesel fuel. We, initially run the engine at Zero load at take readings of all the parameters required for our performance checks. Following parameters are to be noted:-

- Air Velocity in the air passage (m/s)
- Fuel consumption (ml/minute)
- Temperatures:
  \[ T_1 = \text{Temperature of the water entering into the engine jacket.} \]
  \[ T_2 = \text{Temperature of the water coming out from the engine jacket.} \]
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$$T_3 = \text{Temperature of the Exhaust gases entering into the exhaust calorimeter.}$$

$$T_4 = \text{Temperature of the Exhaust gases coming out from the exhaust calorimeter.}$$

$$T_5 = \text{Temperature of the water entering into the Exhaust Calorimeter.}$$

$$T_6 = \text{Temperature of water coming out from the Exhaust calorimeter.}$$

1. Load on the engine applied by the Belt Dynamometer.(Kg.)
2. Water flow to the engine Jacket and To the Exhaust Calorimeter.(Liter per Minute)
3. After noting down all the parameters, we apply a load of 1 Kg on the engine and let it run for 15 minutes to achieve the steady state and then point down all the parameters again.
4. In the same manner, we increase the load to 2 kg than 4 kg and than 8 Kg and note down all the parameters like before.
5. The results of the experiment are tabulated. These are our reference values.
6. The same was repeated with Neat Karanja Biodiesel.
7. In the next phase, we introduce LPG with the Bio Diesel and note down the readings. In this stage,
8. We have to take reading of one additional parameter i.e. LPG fuel consumption. We measure the LPG gas velocity with the help of a Hot Wire Anemometer and then covert it into volume flow rate as discussed in earlier sections to measure its quantity in m3/s or mass flow rate in Kg/s or Kg/hr.
9. After all the values are obtained, these values are scrutinized for the preparation of final results and for comparing the performance parameters.

8. RESULTS AND DISCUSSION

The results are then tabulated and calculated thus for the results and then plotted in the terms of line graphs. 5 different graphs have been plotted and discussed.

8.1. Fuel Consumption vs Load

Graph 1 Fuel consumption Vs Load

The above graph shows fuel consumption in different cases and in dual fuel mode, it shows consumption of biodiesel alone. It is evident from the graph that neat biodiesel has the highest consumption profile at all the loads, and mixing LPG reduces the consumption of biodiesel. 3 different & constant flow rates of LPG of 0.094, 0.189 & 0.283 Kg/hr are experimented and observed. It was found that
biodiesel consumption was lowest in the case of LPG flow rate of 0.283 Kg/hr. at this mode the biodiesel consumption at no load was 0.282 kg/hr. while the consumption in case of neat biodiesel at no load was 0.357 kg/hr which is 0.075 kg/hr more than the former. At full load, the consumption figure for dual fuel (LPG at 0.283 Kg/hr) was 0.642 kg/hr. while neat biodiesel was consumed at 0.730 kg/hr which is 0.088 kg/hr more than former. Thus it is apparent that at high loads, dual fuel is more efficient. Consumption of Neat diesel was lower than neat Biodiesel at all loads and at low loads dual fuels were better than neat diesel but at higher loads diesel consumption was the lowest than all other fuels and fuel combinations.

8.2. Brake Specific Fuel Consumption vs Load

Graph 2 Brake Specific Fuel Consumption Vs Load

Brake specific fuel consumption states that how much amount of fuel is consumed for generation of per unit brake power. It is governed by the quality of the combustion of fuel. As brake power varies with load thus BSFC also changes with load. The Graph above denotes that. The graph shows the consumption of diesel, biodiesel and only biodiesel in dual fuel mode for generating per unit brake power. It is clear from the graph that Neat biodiesel has highest BSFC at all loads closely followed by neat Diesel and overlapping at low loads. The dual fuel league show close results at all loads, and at high loads their difference is negligible. BSFC reduces with increasing loads as at high loads fuels completely burns and low emission wastages appear. In dual fuel mode, LPG induction helps in reducing ignition delay and helps in providing complete and smoother burning of fuel thus BSFC reduces. At 1 kg load and top load, in Neat biodiesel case, BSFC was 1.63 & 0.37 kg/kwhr. while in dual fuel mode (LPG flow rate of 0.283 Kg/hr) it was 1.14 and 0.23 kg/kwhr at no load and top load respectively i.e. there was an improvement of 30.06% at no load and 37.83% at top load. With LPG flow rate of 0.189 Kg/hr these improvements were 27.60% & 32.43% at 1 kg load and top load respectively.
8.3. Brake Specific Energy Consumption vs Load

Graph 3 Brake Specific Energy Consumption Vs Load

Brake specific energy consumption shows the required energy of the fuel for generating per unit of brake power. In this graph total energy content of the fuels in dual fuel mode has been taken in account. It is apparent that greatest amount of energy per unit brake power was used in dual fuel modes at LPG flow rates of 0.283 Kg/hr followed by LPG at 0.189 Kg/hr. The cause behind this is the high calorific value of LPG, with increment in the amount of LPG, much energy goes non utilized in form of unburned HC thus BSEC increases. Neat biodiesel shows lower BSEC than all other fuels at all loads except than of neat diesel which shows better BSEC at high loads.

8.4. Brake Thermal Efficiency vs Load

Graph 4 Brake Thermal Efficiency Vs Load

Brake thermal efficiency is a dimensionless number which indicates the extent to which energy given by the fuel is converted to brake power i.e. net work output. Here in this graph it is represented in percentage. BTE is directly proportional to Brake power and inversely proportional to energy content of fuel. Thus with increase in brake power or load it increases. In our experiment, neat Biodiesel showed better BTE
just next to diesel which showed better BTE at all load among all fuels. With the increment in the quantity of LPG, BTE reduces as total energy content of the fuel increases. The poorest BTE thus, was observed in dual fuel mode with LPG flow rate of 0.283 Kg/hr. higher calorific value of LPG fuel an its poor utilization inside combustion chamber reduces the BTE.

8.5. Exhaust Gas Temperature vs Load

EGT is an important parameter in engine performance check, it is an indication of how hot the combustion process is in the cylinders, and the amount of "afterburning" that is occurring in the exhaust manifold. EGT is also directly related to the air/fuel ratio. The richer the air/fuel ratio in a diesel, the higher the EGT will be. Two things can create a rich mixture under heavy loads or at full throttle: the first is too much fuel, and the second is not enough air. That seems simple enough, but it's the second part, not enough air, could get an engine in trouble. Anything that restricts intake airflow, or intake air density, limits the air mass or amount of oxygen that gets to the cylinders for supporting the combustion of fuel. This could include: a dirty or restrictive air cleaner, a partially blocked air intake, high outside air temperature, high altitude, restricted airflow to or through the radiator or intercooler, and high water temperature.

Looking at the graph, it is obvious that with increase in load the EGT increases, but the increment is not linear. Higher EGT’s were observed in dual fuel modes, the causes of it may be less air for combustion in the combustion chamber and high heating value of LPG gas. Neat Biodiesel shows fairly low EGT than all other fuels at all loads except of neat diesel at high loads. The cause behind this may be large amount of biodiesel consumed at higher loads causing high EGT’s. In dual fuel league, 0.189 & 0.283 Kg/hr LPG flows shows approximately similar temperatures, and 0.3 m/s flow shows a little lower temperature at top load. 0.094 Kg/hr follows closely the temperature curve of neat diesel at lower loads and of biodiesel at higher loads.

The highest temperature observed was 228°C in dual fuel mode of 0.283 Kg/hr LPG flow at full load while in neat biodiesel highest temperature observed was 219°C at top load.
9. CONCLUSION

A comprehensive experimental work on the performance measurement of diesel engine running on 100% KOME biodiesel and to convert it into dual fuel engine with the help of LPG kit has been carried out successfully. Following important outcomes derived from the experiment.

1. Fuel consumption was reduced in dual fuel mode. At no load, biodiesel consumption was 0.357 while with LPG at 0.094, 0.189 & 0.283 Kg/hr it was 0.334, 0.292 & 0.282 kg/kwhr respectively. Thus there was a saving of 6.44%, 18.20% & 21.00% respectively. At top load of 8 kg, the savings were 4.38%, 8.356% & 12.05% respectively. Thus at higher loads savings were not as good as lower loads.

2. BSFC also got reduced in dual fuel mode. At 1 kg load, the improvement in dual fuel mode at LPG flow rates of 0.094, 0.189 & 0.283 Kg/hr were 16.56%, 27.60% & 30.06% respectively. While at top load of 8 kg these improvements were 32.43%, 32.43% & 37.837% respectively. It is quite clear that BSFC was largely improved in dual fuel mode.

3. BSEC and BTE didn’t got improved in dual fuel modes, although low LPG flow rates give comparable results in BSEC but not in BTE, increased concentration of LPG in successive stages worsen the BTE. The higher calorific value of LPG and lower utilization of it causes to reduce BTE by increasing the overall non utilized energy input to the engine. This can be overcome by using advance techniques such as electronically timed and controlled injection of fuel to determine the needed quantity of fuel in engine, exhaust gas recirculation to utilize unburned HC, glow plugs for reducing the ignition delay at higher speeds and loads and additives for the biodiesel to reduce its density etc. although, it is still unsure that they will improve BTE to great extent but keeping in mind that biodiesel is a future fuel, it needs to be worked out.

4. Exhaust gas temperature increased in dual fuel modes. The high heating value of LPG is the main cause behind it. Better cooling systems in which the cooling fluid quantities are also changeable are needed to employ dual fuel systems in diesel engines to keep the EGT in limit at higher loads. High temperature inside the combustion chamber may also harm the engine parts and reduce the mechanical strength it is very essential to take care of cooling inside the combustion chamber.

5. The cost of cooking LPG used is around 32 INR per kg in India while the biodiesel that we made at laboratory in the university costs us 265 INR per Liter which is quite high because of high cost of raw materials used in making it. It’s very important to make biodiesel at large levels to bring its cost down otherwise it will not become popular and researches will be disappointed morally.

6. None of the LPG /Bio Diesel mix systems examined has resulted in Biodiesel consumption being reduced by more than 21%. Those savings made also have LPG costs (for the LPG that replaces some of the biodiesel fuel consumed) subtracted from that 21% saving. Due to cause of insufficient utilization of LPG, the savings do not come huge but research and technology in future will definitely fill this gap and make biodiesel –LPG a popular fuel.

7. There are other problems to consider as well - The unmodified Diesel engine was relatively slow-revving, producing its maximum torque at lower RPM than a similar Petrol version and was used to run with fuels having density like diesel. This is not the case when it is converted to run on biodiesel and LPG mix. The revised engine has to 'rev' more when running on biodiesel / LPG mix because its maximum torque will have been moved higher up the rev. band. This can bring new problems of reliability and longevity. The crankshaft, bearings and connecting rods (to mention but a few components) were all designed to rev. at a lower rate. These components will suffer much higher stresses (stress increases at the square of RPM) at the
increased RPM necessary to get sufficient torque when running on LPG. Mechanical breakdown may result in far less time, whilst increased wear and reduced component life are certain. Also, the high density of biodiesel clogs the engines valves sometime and if not perfectly treated before operation may wear the engine more rapidly. If not taken care of the issues, this does not seem to be an economically viable alternative. But as we know, diesel reserves are depleting, we must concentrate on improving biodiesel performance and technologies for improving it.

Thus as a conclusion, the fumigation method used in this experiment does not appear to be an attractive or useful alternative for the average diesel engine. Also the biodiesel –LPG mix isn’t viable until cost issues and chemical issues are solved. But as far as future is concerned, biodiesel seems to be a perfect alternative for diesel, only more researches on engine design and fuel utilization are needed to be done.

10. SCOPE OF FUTURE WORK

Biodiesel has a great importance in alternative fuel league and is most viable future fuel for running the workhorses. Its low calorific value problem can be eliminated with the help of dual fuel techniques where it can be either mixed with the LPG or CNG or Natural gas which has greater calorific values. The high density problem must be taken into account and research must be done to make its density comparable with petroleum diesel so that clogging and choking, cold start, sludge in engine kind of problems could be eliminated. To improve the performance of a dual fuel engine, a turbocharger to provide more air (or oxygen) for the combustion, must be installed. It will help in complete combustion of fuel and will reduce exhaust gas temperature thus improving the engine life. Apart from that, precise electronic control system must be installed to watch the combustion patterns and needs in combustion chambers and for providing best ratio of biodiesel and LPG. A good exhaust gas recirculation system monitored electronically must be employed to engine to utilize any unburned HC. Some advance additives and catalyst might be added to fuel for smoother and efficient combustion. The concept of present work might be employed with some modifications and with other fuels such as CNG and Natural gas.

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