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Experimental Investigation On LPG-Biodiesel (Pongamia) Dual Fuelled Engine

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Abstract**—** Using renewable fuels for transportation and power generation is one of the approaches for sustainable energy solution for the future world. Dual fuel approach is the one of the techniques. In this project, utilization of Liquefied Petroleum Gas (LPG) as a primary fuel and biodiesel from pongamia pinnata as a pilot fuel used in a compression ignition engine. The LPG-biodiesel dual fuel engine performance and emission characteristics were studied and the dual fuel engine results were compared with neat diesel operation. In this experimental work by varying the LPG flow rates, performance and emission characteristics of the engine were measured. The exhaust gas components such as smoke and CO_2 were quiet decreased while comparing with the base fuel. The optimized NOx emission was obtained as compared with base fuel.

*Keywords***—** Diesel, biodiesel, LPG, performance, emissions.

I. INTRODUCTION

In the modern world, pollution levels are increasing to a great extent mainly due to vehicle exhaust emissions. The depleting reserves of petroleum and high levels of pollutants in vehicular exhaust, it is very important to find a best alternative fuel for our future. In recent years, there has been a significant increase in research into the use of bio-fuels as a substitute for mineral fuels. The dual fuel approach is a well-established technique to make use of different fuels in diesel engines. For substituting petroleum fuels used in IC engines, fuel of bio-origin provides a feasible solution to the twin crisis of “fossil fuel depletion” and “environmental degradation”. The importance on controlling emissions from automobiles while improving fuel economy has increased a substantial research and development effort in pollution control. As a result, control technology and the understanding of pollutant formation mechanisms have been developed rapidly during the past decade.

[3]. Although diesel engines are more efficient than spark ignition engines, emissions from the diesel engine are typically higher. It remains the main obstacles for the increasing application of diesel engines with the increasing concerns for environmental protection and implementation of exhaust emission controlled technologies.

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Diesel is becoming scarce, because there is a need to preserve diesel for only locomotive and agriculture uses. For power generation, alternate fuels should be used wherever possible so that diesel is conserved and made available for it primary uses. This will also save sizable for an exchange, as we import considerable amount of crude oil to meet our needs of diesel and petroleum products. Due to environmental and health issue regulators put a lot of restriction to diesel engine because of gaseous emissions like CO and NO_x emissions [4]. The present research focused on the awareness where concentrated fuel diversification and different method for controlling emissions from these engines. And moreover increasing price of conventional fuels have lead to the creation of room to promote and further focused on alternative fuel sources for conventional internal combustion engines. The advantages of LPG in IC engines are reduced deposits, no fuel dilution of engine oil as gasoline engine. Also LPG engines have advantage of reduced cylinder wear and extended engine life. The potential benefits of using LPG in diesel engines are both economical and environmental. And also many researchers show that using biodiesel in diesel engines hydrocarbon (HC), carbon monoxide (CO) emissions were reduced but nitrogen oxide (NOx) emission quiet increased [5]. The oxygen content of biodiesel is an important factor in the NOx formation, because it causes to high local temperatures due to excess hydrocarbon oxidation. Biodiesel is usually produced by the transesterification of vegetable oils or animal fats with methanol or ethanol. This source of biodiesel is attracted considerable attention during the past decade as are renewable, biodegradable, eco friendly and non toxic fuel. Several processes have been developed for production of biodiesel. Methyl esters (biodiesel) are a clean burning fuel with no sulphur emission. Methyl esters are non corrosive and are produced at low pressure and temperature conditions and gives methyl ester (80%) and glycerine (20%) as a by-product [12]. Previous study stated that 4.8:1 molar ratio of methanol to vegetable oil leads to 98% conversion. G.A.Rao noted that the ratio of greater than 5.25:1 interfered with the gravity separation of the glycerol and added useless expense to the separation. Performance were studied the effect of molar ratio of methanol to oil and effect of changes in concentration of monoglyceride on ester yield. He obtained results form ethanolysis of sunflower oil, in which the molar ratio varied from 6:1 to 1:1 and concluded 98% conversion to ester was obtained at a molar ratio of 6:1. By introducing both LPG and biodiesel in CI engines it will yield the benefits of both fuels [13].

In this paper, the utilization of liquefied petroleum gas (LPG) as a primary fuel with bio-diesel (pongamia pinnata) as a pilot fuel in a direct injection diesel engine. Primary fuel is directly inducted into the engine intake manifold while pilot fuel is injected to the engine cylinder at the time of end of compression stroke. The performance and emission characteristics of the LPG – biodiesel dual fuelled engine and the diesel engine are compared and analyzed.

II. MATERIALS AND METHOD

A. EXPERIMENTAL FUELS:

LPG is an exceptional energy source due to its origin, benefits, applications and its industry. With an immediate and global availability, environmental benefits, its natural by-product origin, transportation flexibility and diverse application, LPG plays a pivotal role in the transition towards a more secure, sustainable and competitive energy model. LPG is a naturally occurring by-product of natural gas extraction (60%) and crude oil refining (40%), therefore we either use it or it is wasted. LPG is primarily a combination of propane and butane molecules, along with trace amounts of other compounds. In the past, LPG was destroyed through venting or flaring (i.e. the burning off unwanted gas), wasting the full potential of this exceptional energy source. At a normal temperature, LPG is a gas. When subjected to modest pressure or cooling, it transforms into a liquid which is easy to transport and store.

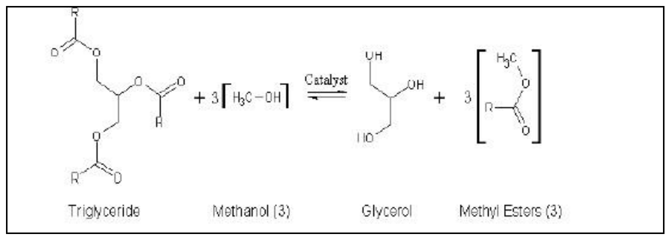
Vegetable oils are extracted from the oil bearing vegetable seeds. Some of the vegetable oils are derived from soya bean, mustard, sunflower, corn, palm, castor, jatropha, pongamia and neem. From the above vegetable oils, only non-edible oils can be used as a raw material for bio-diesel production. Non-edible oils of Jatropha curcas and pongamia pinnata are evaluated as diesel fuel extender. Initially pongamia oil is derived from the pongamia pinnata tree seeds. Afterwards, bio-diesel is derived from the transesterification process. Transesterification is the process in which the reaction of triglyceride with an alcohol in the presence of acidic or alkaline as a catalyst to form mono alkyl ester that is biodiesel and glycerol.

To prepare biodiesel from pongamia oil, first sodium hydroxide was added in to the methyl alcohol to form sodium methoxide; simultaneously oil was heated in a separate vessel of transesterifaction reactor and subjected to heating and stirring. When temperature of oil reached at 60°C then sodium methoxide was mixed in to the oil and reaction mixture was stirred for one and half hour. After reaction completion, the reaction mixture was transferred in separating funnel. The mixture of glycerol and methyl ester was allowed to settle for 8 hours. After settling for 8 hours glycerol and methyl esters was separated manually. The methyl ester was the washed with hot water to remove traces of sodium hydroxide impurity. The washed biodiesel then distilled to remove moisture and final good quality biodiesel was subjected for chemical analysis.

Transesterification reaction:

Biodiesel which is derived from triglycerides by the chemical process known as tranesterification. The tranesterification process is the reaction of triglyceride (fat/oil) with an alcohol in the presence of acidic, alkaline or lipase as a catalyst to form mono alkyl ester that is biodiesel and glycerol. However the presence of strong acid or base accelerates the conversion. It is reported that alkaline catalyzed transesterification is fastest and require simple set up therefore, in current study the oil of pongamia pinnata were transesterified with methyl alcohol in the presence of strong alkaline catalyst like sodium hydroxide or potassium hydroxide in a batch type transesterification reactor. The transesterification reaction is given below and this process has been widely used to reduce the high viscosity of triglycerides.

Transesterification process:



B. Experimental setup:

The engine used in this study is single cylinder, four stroke, water cooled diesel engine. The specifications of the engine are given in Table-II and block diagram for the experimental set up is shown in Fig.1. The engine is fully instrumented for measurements of necessary operating parameters and combustion data. High and low speed data acquisition systems are used to collect the inquired data. A special arrangement is used for inducting LPG into the engine using a pressure regulator, flame trap and a bypass valve. The specification of the dynamometer is given in Table- III.

C. Experimental Procedure:

The test bench consists of naturally aspirated, single cylinder four stroke water cooled diesel engine of Kirloskar TV1 make. The engine has a rated power of 5.9 kW. The engine is converted to dual fuel mode of using bio-diesel as a pilot fuel and gaseous fuel (LPG) as the main fuel with air in a naturally aspirated engine. The LPG gas is inducted into the inlet manifold of the engine using a bypass valve. While supplying the gaseous fuel, the LPG cylinder is connected to the engine through a pressure regulator and flame trap. The purpose of flame trap is to extinguish the flame in case of any back fire.

Initially the engine was started by cranking and the decompression lever was used for easy cranking. The engine is allowed to run and attain the steady state using diesel. The engine is shifted to dual fuel mode by means of opening the

LPG bypass valve. At each load engine is operated dual fuel mode with three different LPG flow rates. The load is applied in kg and at each load the time taken for 50cc of fuel consumption is noted down. At each load manometer reading and emission characteristics are noted down.

III. Result and Discussions

A. Performance characteristics:

Brake thermal efficiency (BTE): BTE for various LPG flow rates were observed. The plot of BTE against brake power is shown in Fig .2. The comparison of BTE for LPG flow rate 2, 4 and 6 g/min are shown in the graph. It is found that LPG flow rate of 2 g/min gives better BTE at all loads as compared standard diesel. This may be attributed to extra oxygen content of biodiesel blends which improves the combustion process tending to increase in BTE of the engine. But with increase in substitution of LPG the BTE gradually falls at part load conditions, because at low loads less pilot fuel is impinged into the cylinder, and due to the excess air and low cylinder temperature, lean amount of fuel mixture escapes into the exhaust. While for diesel, BTE increases at higher load upto 20% of the LPG substitution. At higher load the increase in average gas temperature has the effect of reducing the fuel resulting in an improved BTE.This may be due to extra oxygen content of biodiesel which improves the combustion process tending to increase in BTE of the engine. The dual operation with LPG and bio-diesel fuel improves the brake thermal efficiency by 3-4%. This may due to the reduction in delay period of bio-diesel and an increase in mixture temperature and due to the higher calorific value of LPG fuel than diesel fuel.

Brake specific consumption (BSFC): BSFC of the dual fuel mode is recorded with biodiesel and LPG. It is observed that by increasing load, BSFC decreases. A cylinder pressure and temperature increase, which improves the combustion process resulting in decrease in BSFC.The BSFC decreases with increasing percentage of LPG substitution at peak loads, may be due to complete combustion of the gaseous fuel. As shown in Fig .3, the specific fuel consumption first increases, then decreases with the increase of LPG flow rate from 2-4 g/min. After the addition of LPG flow rate the specific fuel consumption increases for the brake power above half load condition. This may due to the incomplete burning of LPG due to insufficient oxygen.

B. Emission characteristics:

Carbon monoxide (CO): CO emissions from the engine occur due to partial oxidation of the fuel mixture. The rate of CO formation is a function of unburned fuel and mixture temperature during combustion. The variation of CO emissions against brake power is shown in Fig .4.It is observed that with increase of substitution of LPG, the CO emission decreases upto 30% at part load as compared with neat diesel. The CO emission is increased for higher loads and for the all LPG flow rates. CO emission increases with increase o f LPG fuel flow rate for the minimum load condition. This may be due to reduction in fresh oxygen leads to partial oxidation of the fuel mixture.

Hydrocarbons (HC): The comparisons of hydrocarbon emissions for straight diesel, biodiesel and biodiesel-LPG in dual fuel mode are shown in Fig.5. While compared with base diesel, hydrocarbon emission was found in increasing rate with increased LPG flow rates in biodiesel-LPG mode. It may be due to insufficient ignition sources resulted in incomplete combustion. From the Fig.5,it is found for there is no major variations for the LPG flow rate of 2kg/min and 4kg/min.

Oxides of nitrogen (NO_x): NO_X formation rate depends upon in-cylinder gas temperature.NO_X forms at high temperature burned gas regions. The comparison of variations of NOx emission with LPG substitution is shown in Fig 4. There is a reduction was observed in NOx emission upto part load levels. It is evident NOx is decreased with increase of LPG flow rate. This may due to reduction in fresh air and high self ignition temperature of LPG, which increases the ignition delay resulting into reduced cylinder peak pressure temperature. The variation of NO_X emission with load 4g/min of LPG flow rate are shown in Fig.4.It is observed that for higher loads NO_X emission increased.

Table I: Properties of diesel, biodiesel and LPG

Property	Diesel	Biodiesel (pongamia)	LPG
Density (kg/m^3)	830	890	493
Kinematic viscosity at 35°C (cS)	2.7	5.9	-
Auto ignition point(°C)	250	-	500
Cetane number	48	42	-
Lower heating value(MJ/kg)	43.35	37	46.36

Table II: Engine specification details

Engine	Single Cylinder,4 stroke Diesel – Kirloskar engine
Rated power	5.9 kW
Rated speed	1800 rpm
Bore	87.5 mm
Stroke	110 mm
Capacity	661 cc
Compression ratio	17.5
Dynamo meter	Eddy current dynamometer

Table III: Dynamometer specification

Dynamometer type	Eddy current
KVA	3.5 KVA
Current/voltage	14.6/240V
Phase	Single
Speed	1800 rpm
Power factor	0.8
Frequency	50 Hz
Model	DI

Table IV: Exhaust gas analyzer specification

Parameter	Resolution	Accuracy	Range
Carbon Monoxide	1ppm, mg/m^3	±20ppm <400ppm ±5% >400ppm	0-4000ppm, 0-5000mg/m^3
Nitrogen Dioxide	1ppm, mg/m^3	±5% full scale	100ppm, 200mg/m^3
Carbon Dioxide	0.1%	±0.3% reading	0-99.9%
Carbon Monoxide	1ppm, mg/m^3	±20ppm <400ppm ±5% <5000ppm ±10% >5000ppm	0-10,000ppm, 0-12,000mg/m^3
Hydro carbon	1ppm	±5% of reading	0-5000ppm

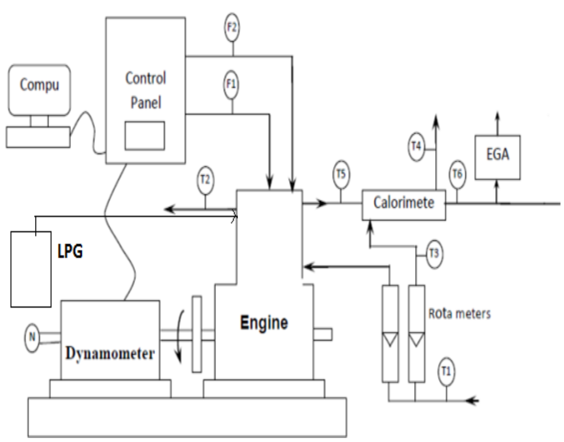


Fig.1 Block diagram of experimental set up

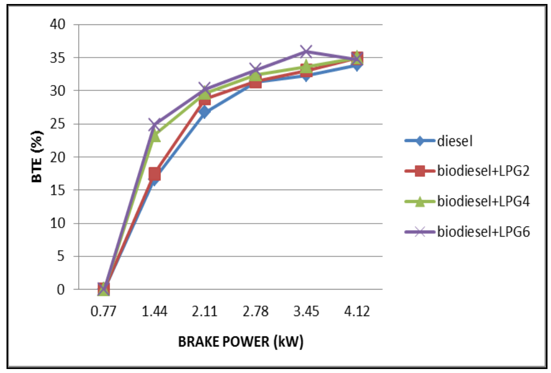


Fig .2 Brake power Vs BTE

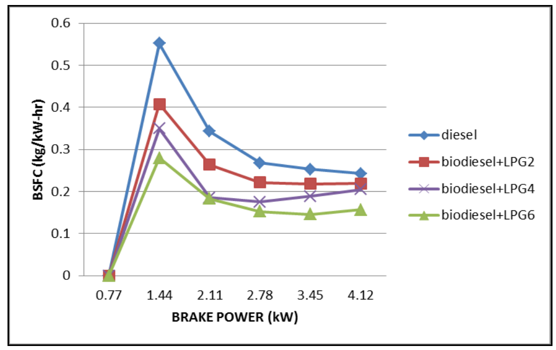


Fig.3 Brake Power Vs BSFC

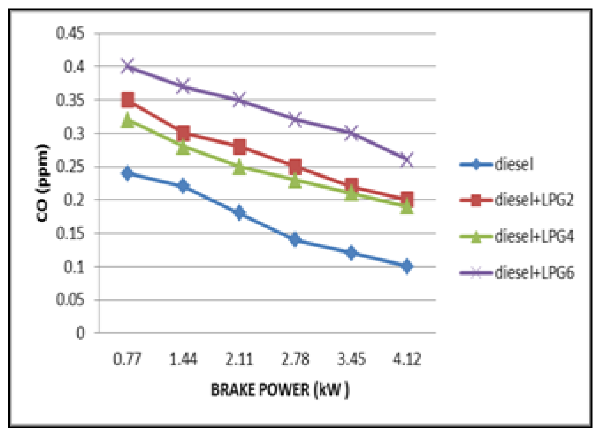


Fig .4 Brake Power Vs CO Emission

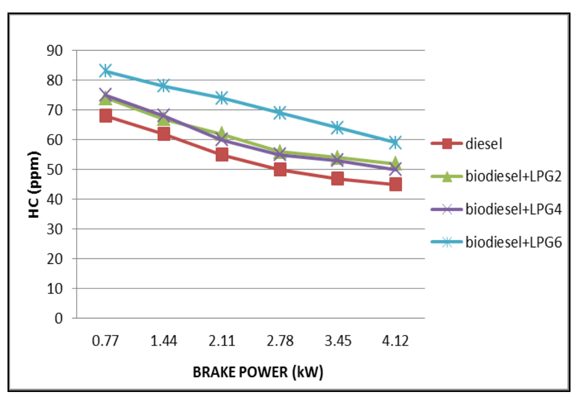


Fig.5 Brake Power Vs HC Emission

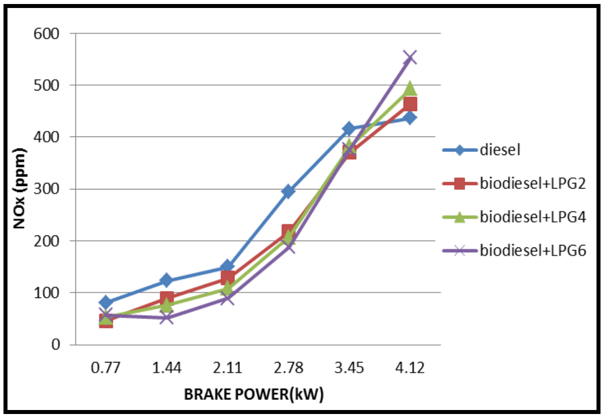


Fig .6 Brake power Vs NO_x

IV. CONCLUSION

In this investigation, experiment has been conducted to examine the effects of induction of LPG into the engine manifold with pongamia pinnatta as pilot fuel. From the experimental analysis, it was observed that engine run smoothly for the LPG flow 2.5-4 kg/min at medium load conditions. Brake thermal efficiency was increased from medium to higher load operations. Optimal specific fuel consumption was observed for substitution of LPG-biodiesel dual fuel mode. NO_x emission was decreased with increase of LPG flow rate. The HC and CO emissions were observed in optimized level in dual fuel mode.

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