© 2015 IJSRSET | Volume 1 | Issue 5 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Performance and Emission Characteristics of Lemongrass Oil Fueled CI Engine

Dr. R. Ramachandra
Principal & Professor, Department of Mechanical Engineering, SKD Engineering College, Gooty, Andhra Pradesh, India

ABSTRACT

The combustion of homogeneous charge compression ignition (HCCI) engine fuelled with neat lemongrass oil, diesel was evaluated the performance and Emission characteristics. In this regard, the combustion phenomena of lemongrass oil were investigated at engine speed of 1500 rpm and compression ratio of 17.5 in a four-stroke cycle engine. Furthermore, the engine tests were conducted with homogeneous charge compression ignition engine. The tests were conducted to measure fuel consumption, indicated power, Brake thermal efficiency, combustion characteristics and compared with conventional diesel fuel operation. The results indicated that the higher specific fuel consumption, the brake thermal efficiency was nearly equal to the diesel fuel. The experimental outcomes disclosed that successful ignition and energy release trends can be obtained from a homogeneous charge compression ignition engine fuelled with lemongrass oil.
Keywords : lemongrass oil, HCCI, Performance, Combustion

I. INTRODUCTION

Rising petroleum prices, increasing threat to the environment from exhaust emissions and global warming have generated intense international interest in developing the alternative non-petroleum fuels for engines. A lot of research work is going on for an alternative fuel. One of the great potential alternative fuels is biodiesel which is produced from vegetable oil and animal fats. For long term, the usage of vegetable oils to produce biodiesel may compete with food supply and they are seasonal and far too expansive to be used as fuel at present [1].

The country has been hit hard by the increased cost and uncertainty and so is exploring other energy sources occurring biodiesel extracted from trees is one such alternative under considerations. Bio-diesel burns cleaner than traditional petroleum diesel fuel and is biodegradable, making it an interesting alternative fuel option in terms of both environmental production and energy independence [2]. Bio-diesel would be cheap to produce as it can be extracted from certain species of tree that are common in many parts of India. Of the various alternative fuels under consideration, biodiesel, derived from esterified vegetable oils, appears to be the most promising alternative fuel to diesel due to the following reasons [3,4].

- Biodiesel obtained from vegetable sources does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues.
- Biodiesel can be used in the existing engines without any modifications.
- Biodiesel is an oxygenated fuel; emissions of carbon monoxide and soot tend to reduce.
- Unlike fossil fuels, use of biodiesel does not contribute to global warming as the CO_2 so produced absorbed by the plants. Thus in nature CO_2 is balanced.
- The occupational Safety and Health Administration classify biodiesel as a non-flammable liquid.
- The use of biodiesel can extend the life span of diesel engines because it is more lubricating than petroleum diesel fuel.
- Biodiesel is mostly obtained from renewable vegetable oils/animal fats and hence it may improve the fuel or energy security and thus leading to economy independence.

Biodiesel is capable of solving the problems of fuel supply in a decentralized fashion and can simultaneously help to reduce environmental related problems [6,7].

HCCI engines are being actively developed because they have potential they have the potential to be highly efficient and to produce low emissions. The new combustion concept, namely homogeneous charge compression ignition (HCCI), has taken the advantage of the working principles of both Spark Ignition (SI) and Compression Ignition (CI) engines. The HCCI engine operates at nearly constant volume combustion, resulting in high thermal efficiency and improved fuel economy. Lower oxides of Nitrogen (NO_x) could be achieved due to localized mixture being relatively lean homogeneous nature [8]. Particulate emission can be reduced significantly due to homogeneous charge combustion. Even though HCCI has the advantage of the high emission reduction potential and improved fuel economy, it has many challenges such as obtaining the homogeneous mixture and controlled auto ignition. In addition, HCCI engines have been shown to operate with a range of fuels, e.g. natural gas, gasoline and bioethanol. Many institutes have already studied HCCI, but only a few of them performed experiments using biodiesel as a potential alternative fuel.

Lemongrass (cymbopogon flexuosus) is a native aromatic tall sedge which grows in many parts of tropical and sub-tropical South East Asia and Africa. In India, it is cultivated along Western Ghats (Maharashtra, Kerala), Karnataka and Tamil Nadu states besides foot-hills of Arunachal Pradesh and Sikkim [9]. Furthermore, lemongrass is a high biomass crop that may have applications for biofuel production. Owing to the content of its high value essential oil, the cost for production of biofuel may be low, since the biomass would be a by-product of essential oil production. Lemongrass may demonstrate to be a new high value specialty crop and a worthy source for biofuel in the southeastern United States (a region known for its hot and humid climate) .

Most of the experiments are conducted in different types of biodiesel prepared from different oils but some of the studies show that neat oils are mixed with diesel fuel and tested in HCCI engine[10].

In this paper, bio-diesel from lemongrass oil and to compare the performance and characteristics of homogeneous charge compression ignition engine using diesel and bio-diesel blends.

The properties of biodiesel fuel have higher viscosity, density and flash point than the diesel fuel [11]. Further the energy content or net calorific value of biodiesel is less than that of diesel fuel. There are various economically and environmental advantages to utilize this unique fuel. Indian Oil Corporation has tied up with Indian Railways to introduce the production of biodiesel producing crops over 1 million square kilometers On 12 September 2008, the Indian Government announced its ‘National Biofuels Policy’. It aims to meet 20% of India’s diesel demand with fuel derived from plants. Biodiesel has physical and chemical properties similar to conventional petroleum-based diesel.

II. MATERIAL AND METHODS

A) Test fuel-lemongrass oil

Lemongrass has a lemony, sweet smell and is dark yellow to amber and reddish in color with a watery viscosity. Lemongrass oil, often found in soaps and perfumes, is used for many beauty purposes. Lemongrass oil contains quanties of Farmesol, Nerol, Citronellal, Myrcene, Geranyl acetate. The lemongrass oils were isolated by the steam distillation method. They were extracted separately from leaves and stalks of lemongrass at certain time based on the optimization range to give a mixture of water/essential oil. Dichloromethane was used to separate the essential oil from the water layer.

In this, in order to understand the effects of LGO usage in CI engine, in cylinder gas pressure traces were examined. Although an in-depth explanation of the combustion process in diesel engine is extremely difficult due to unsteady liquid jet phenomena and mixture of non-uniformity, some useful data to highlight and explain the combustion characteristics of LGO are presented in this work. This was done with an high-resolution data acquisition system.

B) Transesterification of oil

The main aim of transesterfication was to lower the viscosity of vegetable oils. In general, vegetable oil contains 97% of triglycerides and 3 % di- and mono-glycerides and fatty acids. The process of removal of all glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called transesterfication. The vegetable oil reacts with methanol and forms esterified vegetable oil in the presence of sodium/potassium hydroxide as catalyst. Transesterification is crucial for producing biodiesel from oils. The transesterification process is the reaction of a triglyceride (fat/oil) with a bio-alcohol to form esters and glycerol. However; consecutive and reversible reactions are believed to occur. These reactions are represented in equations below:

Triglycerides + ROH = di-glycerides + R1COOR Di-glycerides + ROH=mono-glycerides + R2COOR Mono-glycerides +ROH= glycerol +R3COOR

Catalyst is usually a strong alkaline (NaOH, KOH or sodium silicate) medium.

Alcohol + Ester →different alcohol + different ester.

The first step is the conversion of triglycerides to di-glycerides followed by the conversion of di-glycerides to mono-glycerides and of mono-glycerides to glycerol yielding one methyl ester molecule from each glycerides at each step. Meher et al. reported that the experimental study revealed that the optimum reaction condition for methanolysis of karanja oil was 1% KOH as catalyst. MeOH/oil of molar ratio 6:1 reaction temperature 65^0c, at the rate of mixing 360 rpm for a period of 3 hrs.

TABLE 1. Comparison of neat lemongrass oil with diesel

Properties	LGO	Diesel
Gross Calorific value (MJ/kg)	36.279	43.35
Kinematic viscosity (cst) at40^0c	4.18	3.25
Specific gravity (g/cc) at 27^0c	0.984	0.84
Flash point^{0}c	50	55
Fire point ^{0}c	58	63
Cetane Index	38	45-50

The yield of methyl ester was >85% in 15 min and reaction was almost complete in 2 h with a yield of 97 – 98% with 12:1 molar ratio of MeOH oil or higher, the reaction was completed within 1 h. the reaction was incomplete with a low rate of stirring at high rpm was a time efficient process

Experimental test setup

The engine used in this experiment was a single cylinder, water cooled, kirloskar oil engine, the engine was coupled with an eddy current dynamometer through a load cell. All the experiments were conducted at standard temperature and pressure. The engine is integrated with a data acquisition the system to store the data for the off-line analysis. Cooling water is circulated separately to the engine and the dynamometer at the required flow rates. Necessary provisions are made to regulate and measure through electronic control unit of flow rates of air, fuel and coolant.

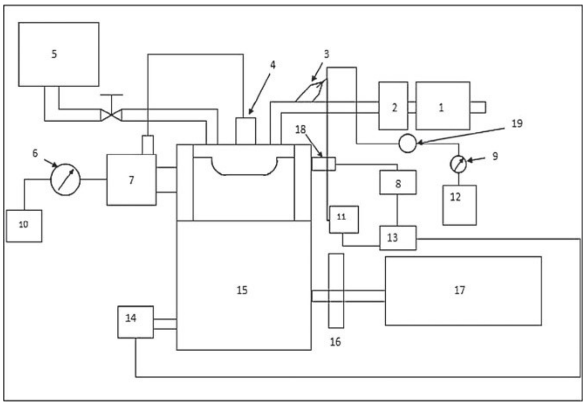

Figure 1. Block diagram of engine

1-Air surge tank
2-Elecric heater
3-Auxillary fuel injector
4-Main fuel injector
5-Exhaust gas analyser
6-Flow meter
7-Fuel injector pump
8-Charge amplifier
9-Flow meter
10-Main fuel tank
11Temperature controller
12-Port fuel tank
13-Data acquisition
14-Crank angle encoder
15-Engine
16-Flywheel
17-Dynamometer
18-Pressure Transducer
19-Fuel control valve

The engine was loaded with eddy current dynamometer and the loads are applied in steps of 0, 25, 50, 75 and 100 percentage of full load. For each load , the engine performance parameters and engine emissions were recorded; the dynamic fuel injection timing was set at 27^0 by BTDC. Fuel consumption was measured by a burette attached to the engine and a stop watch was used to measure fuel consumption time for every 10 cm^3 fuel. Carbon-monoxide, unburned hydrocarbon, and NO_x emission were measured by Wahum Cubic Gas Analyzer. Smoke emissions were measured by means of Bosch smoke meter. Chromyl-alumel (k-type) thermocouple was used to measure the exhaust gas temperature[12]. The engine is started by using standard diesel and the engine operating temperature was reached and then loads are applied. The warm up period ends when cooling water ×temperature is stabilized at 60^0c [13]. The tests are conducted at the rated speed of 1500 rpm. In every test, volumetric fuel consumption and exhaust gas emission such as carbon monoxide, unburned hydrocarbon, nitrogen oxides, are measured. From the initial measurement, brake thermal efficiency (BTE), specific fuel consumption (SFC), brake power (BP), Indicated mean effective pressure (IMEP), mechanical efficiency and exhaust gas temperature for different ratio are calculated and recorded

TABLE II. Engine specification

Engine manufacturer	Kirloskar engines
Bore and stroke	87.5 x 110 (mm)
Number of cylinders	1
Compression ratio	17.5:1
Speed	1500 rpm
Cubic capacity	0.661litres
Method of cooling	Water cooling
Clearance volume	37.8 cc
Nozzle opening pressure	200 bars

III. RESULTS AND DISCUSSION

A. Perfomance analysis

a) Brake thermal efficiency

For neat LGO, brake thermal efficiency is increased by 11 % (at 25% load), 11.7 % (at 50% load), 13.5 % (at 75% load) and decreased by 5.3% (at Full load) because of better vaporization and the combustion chamber surface is relatively hot and that would help in better air entrainment for better mixing.

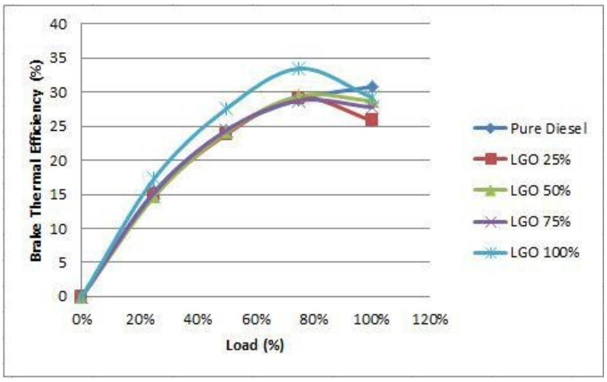

Figure 2. Variation of Brake thermal efficiency and load

b) Indicated thermal efficiency

The graph shows a similar trend for all the loads of operation. For the entire blending ratio, the Indicated thermal efficiencies are nearly equal to diesel fuel except neat LGO (at Full load). For LGO, ITE is increased by 7.3% (no load),

13.6% (at 25% load), 10.3 %(at 50% load), 17.4 %(at 75% load) but decreases at full load by 0.5%.

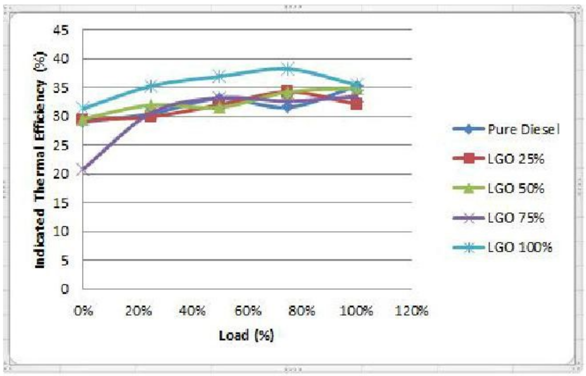

Figure 3. Variation of Indicated thermal efficiency and load

c) Specific fuel consumption

The graph shows a similar trend for all the loads of operation. For all the ratios, specific fuel consumption is increasing while comparing with pure diesel fuel. For LGO, SFC is increased by 6.25 %(at 25% load), 5.5 %(at 50% load), 3.57 %(at 75% load) and 20.8 %(at full load). This could be due to lower calorific value of higher ratios of LGO. But lower values of SFC are desirable one.

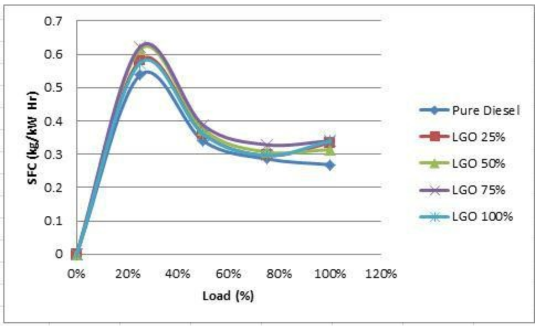

Figure 4. Variation of Specific fuel consumption and load

d) Exhaust gas temperature

The variation of exhaust gas temperature for different ratios of LGO is shown in fig.6. The results indicate that exhaust gas temperature is almost same as that of diesel fuel. The maximum temperature was measured for LGO: 50 at full load of operation (446°C) when compared with diesel fuel (433°C). For LGO: 25 & LGO: 50 the temperature values are lower than that of diesel fuel.

B. Emission analysis

a) NO_x Emission

It is observed that the NOx emission is increasing trend than that of diesel. NOx emission is higher by 23.28% for LGO: 100 at full load condition when compared to diesel fuel and the maximum NOx emission is at 50% load condition (44.06 %) than that of diesel fuel emission. The reason for higher NOx emission could be due to higher peak flame temperature

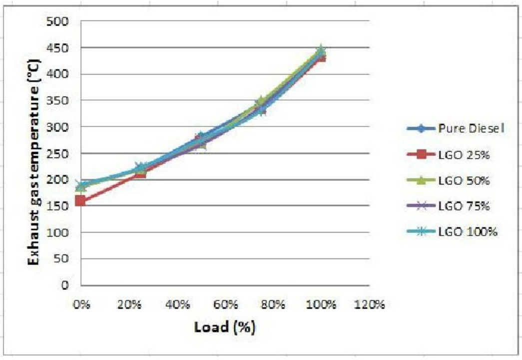

Figure 5. Variation of Exhaust gas temperature and load

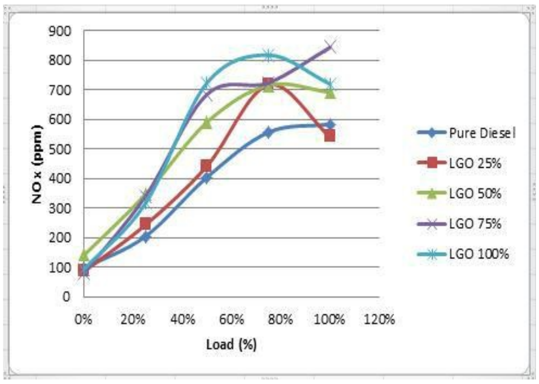

Figure 6. Variation of No_x and load

b) CO emission

CO emission for LGO:75 is very close to diesel fuel emission and it is found that for LGO:25 & LGO:50, the CO emission is higher by 86% and 71% respectively when compared with diesel fuel. This could be due the shortage of oxygen at high speed, and lesser amount of time available for complete combustion and further rising temperature in the combustion chamber, physical & chemical properties of the fuel and A/F ratio.

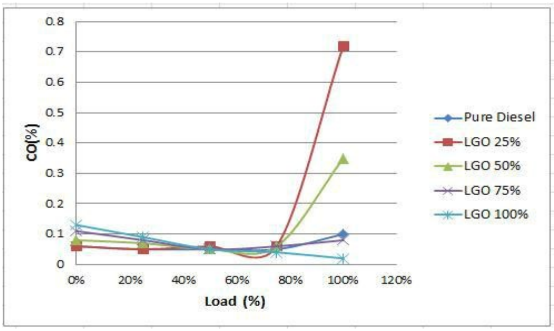

Figure 7. Variation of Co_2 and load

C) Analysis of cylinder pressure data

Combustion in diesel engines is a complex heterogeneous process. Mixture formation and combustion is controlled by interactions between several parameters such as the injection spray, air motion and combustion chamber geometry. Mixture formation and combustion are highly dependent on fuel injection parameters. Precise control of fuel injection and, spray formation and fuel atomization is essential for controlling combustion.

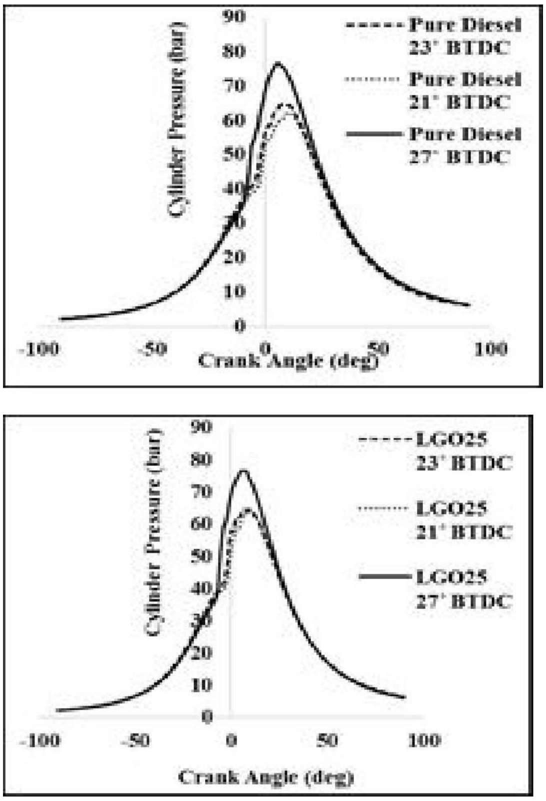

Figure 8. Variation of Heat release rate with Crank angle for LGO-Diesel blends for different Injection timings

If the fuel injection starts later, the temperature and pressure are initially higher but then decrease as the delay proceeds. From the Figure, it is observed that cylinder pressure is increased during the advanced injection timing when compared with other injection timings for all the blends of LGO-Diesel fuels[14]. For Pure diesel, the maximum cylinder pressure is observed as 76.692 bar at advanced injection timing which is higher by 15.5% and 18.71% than the normal and retarded injection timings respectively. For LGO25, the cylinder pressure is increased by 15.7% and 16.1% at advanced injection timing than other fuel injection timings. Moreover, it is increased by 10.2% and 13.42% at advanced injection timing for LGO50 when compared to retarded and normal fuel injection timings respectively. For Neat Lemongrass oil fuel operation, the maximum cylinder pressure is observed as 78.808 bar at advanced injection timing which is higher by 13.95% and 12.4% than retarded and normal injection timings respectively.

D) Ignition delays

Ignition delay is an important parameter in combustion phenomenon for diesel, premixed and neat LGO at different loads. The delay period or ignition delay mentioned here refers to the time difference between the start of injection and start of combustion, that is, time interval during which each fuel droplet gets ready for combustion. This period is generally determined from the change in slope of the pressure versus crank angle diagram or from the heat-release analysis. The time delay decides the quantity of premixed flame. The rate of pressure rise, peak pressure, engine noise, vibrations and mechanical stress also depend on the ignition delay[15]. In general, a lot of parameters such as fuel type and quality, air–fuel ratio, engine speed, fuel atomization, intake air pressure and temperature influence the ignition delay. Among these, the fuel type is an important parameter affecting the delay period. It is also apparent from the table that the ignition delay of diesel is longer than that of premixed LGO (particularly 5%) and neat LGO in the entire engine operation. In spite of the slightly higher viscosity of LGO, the ignition delay appears to be lower for premixed and neat LGO than for diesel. The primary reason may be the complex and rapid pre flame chemical reaction that takes place at high temperatures. As a result of the high cylinder gas temperature, LGO has undergone thermal cracking and lighter compounds might have been produced, which might have ignited earlier to result in a shorter delay period.

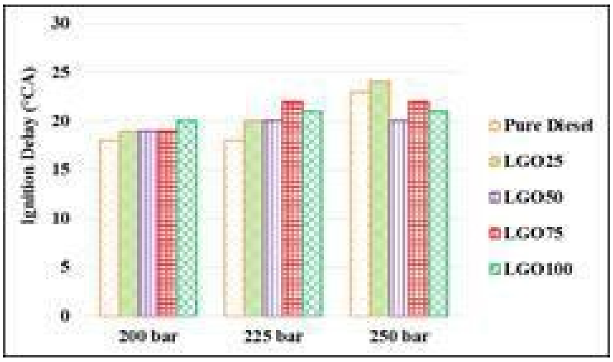

Figure 9. Variation of Ignition delay for various LGO-Diesel blends for various blends

IV. CONCLUSION

The performance, emission and combustion characteristics of a direct injection HCCI engine fuelled with neat lemongrass oil and diesel have been investigated and compared with that of standard diesel fuel and conclude the following aspects.

1. LGO can be used as a sole fuel in engine without any pre-treatment processes such as transesterification, pyrolysis or emulsion.
2. The Indicated thermal efficiencies are nearly equal to diesel fuel except neat LGO.
3. The combustion pressures are increased because of the fuel absorbs more amount of heat from the cylinder immediately after injection and resulting in higher combustion pressure.
4. The heat release rates for LGO ratios are higher than that of diesel fuel. This could be due to the better vaporization and atomization of lemongrass oil inside the combustion chamber and better spray formation
5. For neat LGO, Brake thermal efficiency (BTE) is increased and SFC is increased. This could be due to lower calorific value of higher ratios of LGO. But lower values of SFC are desirable one and also Mechanical efficiency is decreased.
6. Results showed that at lower load conditions only, smoke emissions are higher than the diesel fuel. But for 75% full load conditions, it is observed that lower smoke emissions. This is due to the complete combustion of lemongrass oil in the combustion chamber.
7. On this last concern scientific advancements are fundamentally required in current engine technology to address the global issue on depletion of easily accessible fossil fuels

V. REFERENCES

[1]. Mevlut Sureyya Kocak, Zafer Utlu, "The effect of biodiesel fuel obtained from waste frying oil on direct injection diesel engine performance and exhaust emissions," Renewable Energy, 1936-1941,2008.

[2]. K.Binu , C. Jagdeesh Vikram, S. Prabhakar, "Performance test for lemongrass oil in single cylinder diesel engines," ISSN 1819-6608 ,2013.

[3]. E. Crabbe, A. Ishizaki, C. Nolasco-Hipolito, G. Kobayashi, K. Sonomoto and, "Biodiesel production from crude palm oil and evaluation of butanol extraction and fuel properties," Process Biochemistry,37: 65-71, 2001.

[4]. G. Knothe and K.R. Steidley, "Lubricity of components of biodiesel and petrodiesel: The origin of biodiesel lubricity," Energy and Fuels. 19: 1192-1200, 2002.

[5]. Fangrui Maa, Milford A. Hannab, "Biodiesel production: a review" Bioresource Technology 70, Page 1-15.

[6]. Ma Fangrui, Hanna Milford A., "Biodiesel production: a review," Bioresource Technology," vol. 70, pp. 1 -15

[7]. C.S. Lee, D.S. Kim," Improved emission characteristics of HCCI engine by various premixed fuels and cooled EGR," Fuel, 85: 695-704. 2006.

[8]. Zhao, F., Asmus, T., Assanis, D., Dec, J., Eng, J. and Najit, P,"Homogeneous charge compression ignition (HCCI) engine," Key Research and Development Issues, SAE SP-94. 2003.

[9]. D. Yap, M. Wyszynski and Xu, H, " An investigation into propane homogeneous charge compression ignition engine operation with residual gas trapping", Fuel, 84(18): 2372-2379. 2005

[10]. C. Bae, K. Yeom, J. Jang, " Homogeneous charge compression ignition of LPG and gasoline using variable valve timing in an engine," Fuel, 86(4): 494-503. 2006.

[11]. R. Standing, N. Kalian, Wirth, M, H. Zhao, " Effects of injection timing and valve timings on CAI operation in a multi-cylinder DI gasoline engine", SAE Paper No. 2005-01-0132,2005

[12]. Akhilendra Pratap Singh, Avinash Kumar Agarwal, "Combustion characteristics of diesel HCCI engine: an experimental investigation using external mixture formation technique," Appl. Energy 116-125,2015

[13]. D. Ganesh, G. Nagarajan, M. Mohamed Ibrahim, "Study of performance, combustion and emission characteristics of diesel homogeneous charge compression ignition (HCCI) combustion with external mixture formation," Fuel, 3497-3503,2008.

[14]. A. Babajimopoulos, D. Assanis, S. Fiveland, "An approach for modeling the effects of gas exchange processes on HCCI combustion and its application in evaluating variable valve timing control strategies". SAE 2002-01-2829, 2002.

[15]. K. Soloman Binu, S. Prabhakar, S. Aque Ahmed Ashf, C. Vikram Jagdeesh, "Performance test for lemon grass oil in single cylinder diesel engines source," J. Eng. Appl. Sci. 8, 455-458,2013.