The International Journal Of Engineering And Science (IJES)
|| Volume || 4 || Issue || 5 || Pages || PP.45-55|| 2015 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

A Study On The Performance And Combustion Of A Diesel Engine Fuelled With Biodiesel From Waste Cooking Oil, Its Blends And With An Additive.

[1]Rajagopal. k , [2]Johnson.J , [3]Selwin Rajadurai.J
[1]Department of Physics, Government College of Engineering., Tirunelveli,Tamil Nadu ,India.
[2]Department of Physics, Research scholar, M. S. University, Tirunelveli, Tamil Nadu, India
[3]Department of Mechanical engineerings, Government College of Engineering., Tirunelveli,Tamil Nadu

--ABSTRACT--

This paper highlights the performance and combustion of a single cylinder four stroke diesel engine operated on blends of biodiesel produced from waste cooking oil. An additive Diethyl ether (DEE) has been added in three different proportions to B20 blended fuel to study the effect of additive on the performance and combustion of the diesel engine. Our results conclude that the break thermal efficiencies of the diesel engine show an increasing trend with both blended fuels and additive mixed blended fuels, slightly higher than the case of pure diesel fuel.

Keywords *– Biodiesel, Brake Thermal Efficiency, Ignition delay, Maximum cylinder pressure, Specific Fuel Consumption,*

Date of Submission: 29-April-2015 Date of Accepted: 15-May-2015

I. INTRODUCTION

Research on identifying alternative source of fuel for industrial and transportation sector is intensively taken up by several research laboratories throughout the world as the fossil crude oil is depleting very fast. The world energy forum [1] recently predicted that crude reserve may be exhausted in less than another 10 decades. Furthermore one of the greenhouse gas especially co_2 emitted by transport vehicles operated with conventional diesel fuel is alarmly polluting the atmosphere. Since early 1980's researchers from developed countries started producing biodiesel from edible sources like palm, soya, corn and peanut etc., and many western countries have already using the blending of biodiesel up to 20% in transportation sector. However in developing countries like India, where human population is higher, every attempt is made to produce biodiesel from non-edible seeds such as Karanja, Neem, Calophyllum inophyllum and rubber seeds etc., in order to avoid man versus food conflict. In continuation of our research work by our group on the production of biodiesel form some non edible seeds like karuvel and salicornia [2, 3], biodiesel has also been produced from waste cooking oil [4] recently. India imports nearly 14 billion tons of edible oil for internal use, and even if 10 percent of this oil is thrown as waste, after used in food process, it comes around 1.4 billion tons. Thus if this amount of waste oil is collected, instead of thrown on land mass or water bodies, not only the pollution may be reduced but also a viable biodiesel source is available to meet the industrial and transportation sector's needs thereby saving foreign exchange considerably.

This paper highlights the performance and combustion of a single cylinder four stroke diesel engines operated with five biodiesel blended fuels (B5, B10, B15, B20 and B25) derived from waste cooking oil. Furthermore, diethyl ether has been added to B20 blends to study the effect of additive on the performance and combustion characteristics of the diesel engine using additive mixed blended fuels (B20A5, B20A10 and B20A15). It is well known that DEE is also an excellent ignition enhancer and has a low auto ignition temperature [5]. Furthermore, Diethyl ether (DEE) is an oxygenated additive can be added to diesel/ biodiesel fuels to suppress the NOx emission. The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. EXPERIMENTAL

2.1 Preparation of waste cooking Oil

The waste used cooking oil has been collected from GCE College hostels and filtered by filter paper couple of times to remove impurities present in the oil. The filtered clean cooking oil has been then used for the experiment.

2.2 Chemicals and reagents

The chemicals and reagents (Potassium hydroxide (KOH) in pellet form, anhydrous Na_2So_4, Methanol and Diethyl Ether) have been used in this study are of AR grade with purity >99% procured from Highmedia laboratories Pvt. Ltd., India. These chemicals have been used without any further purification.

2.3 Experimental setup to produce biodiesel

The reactor(Fig 1) used for experiments is a 5000 ml five-necked round-bottomed flask placed over the heating mantle. The central neck has been connected to a stirrer. The stirrer rod is attached to a motor on the top and a propeller at the bottom. The stirrer rod is passed in to the reactor through a tightly packed hole in the rubber cork placed on the central neck to make sure that the reactor is airtight. The stirrer is driven by an electric motor equipped with a speed regulator. The purpose of the stirrer is to mix the reactants thoroughly. The second neck is equipped with a reflux condenser (for preventing the methanol from escaping out of the reactor). Third neck is used for thermo-well. A platinum RTD temperature sensor (PT-100) has been placed in the thermo-well for temperature measurement inside the reactor. The sensor has been connected to a digital temperature indicator and a Proportional integral derivative (PID) controller to control temperature of reaction mixture. Fourth neck is used for loading the reactants in to the reactor while the fifth neck is closed with air tight Rubber cap.

2.4 Production of biodiesel by transesterification

The type of transesterification process is determined by the Free Fatty Acid content (FFA) present in the oil which is related, by its acid number. The acid number of any oil has been defined in terms of the number of milligrams of KOH required to neutralize the free acids present in 1 gm of oil. If the Free Fatty Acid number is less than 2% then single step transesterification process is followed using alkali catalyst only. However, if the Free Fatty Acid content is greater than 2 %, then two steps transesterification process have to be followed in steps using acid and alkali catalyst respectively. In the present investigation, the FFA content of waste cooking oil has been found to be 0.9848%, and hence single step transesterification process as discussed in the succeeding section has been followed.

Fig 1.Biodiesel production plant

Transesterification also called alcoholysis, is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis except that an alcohol is used instead of water [6]. This has been widely used to reduce the viscosity of the triglycerides. The transesterification is represented as

$$\underset{\text{Ester}}{RCOOR'} \quad + \quad \underset{\text{Alcohol}}{R''OH} \quad \leftrightarrow \quad \underset{\text{Ester}}{R'COOR''} \quad + \quad \underset{\text{Alcohol}}{ROH}$$

If methanol is used in this process then it is called methanolysis. Methanolysis of triglycerides is represented as

$$\begin{array}{llllll} CH_2COOR_1 & & & & CH_2OH & R_1COOCH_3 \\ + & & & & & \\ CHCOOR_2 & + & 3CH_3OH & \xrightarrow[KOH]{CATALYST} & CHOH \quad + & R_2COOCH_3 \\ + & & & & & \\ CH_2COOR_3 & & & & CH_2OH & R_3COOCH_3 \\ & & & & & \\ \text{Parent oil} & & \text{Methanol} & & \text{Glycerin} & \text{Methyl ester} \end{array}$$

2000 ml. of waste cooking palm oil free from water and contaminants has been taken in the biodiesel round bottomed flask. The base catalyzed trans-esterification reaction has been carried out with methanol to oil ratio as 1:4 v/v. Potassium hydroxide (KOH) has been used as catalyst at 1% w/v of oil. The oil, preheated to 60°C in a heating mantle for about 5 - 10 min, has been used in order to achieve the maximum yield. Initially Potassium hydroxide (KOH) has been added to the preheated oil. The reactant mixture has been stirred continuously at the rate of 600 rpm and the temperature of the reactants has been maintained at 60°C. The system has been maintained airtight to prevent the loss of alcohol. Reaction has been carried out for 1 hour.

These optimum values have been found by comparing the yield of methyl esters from several reaction ratios. After the attainment of preestablished time, the mixture has been carefully transferred to a separating funnel and allowed to stand overnight. The lower layer (glycerol, methanol and most of the catalysts) has been suitably drained out. The upper layer that consists of methyl esters, some methanol and traces of the catalyst has been washed with warm doubly distilled deionised water (70°c) in order to remove the impurities like uncreated methanol, uncreated oil and catalyst. The methyl ester has been finally heated to 110°c then dried with anhydrous Na_2So_4 to get rid of any water [7].

The biodiesel yield in the present case has been calculated using the following equation.

$$\text{Biodiesel Yield} = \frac{\text{Mass of biodiesel } \textbf{produced} \ x\ 100}{\text{Mass of waste cooking oil used}}$$

Our experimental investigation reveals that, the yield of the biodiesel is approximately 85% .The produced biodiesel has to be checked for its applicability as an alternative fuel in Diesel engines by measuring some of its physical and thermo dynamical properties as briefed below.

2.5 Characterization of Biodiesel, Blended fuels and Additive mixed blended fuels using Physical and thermo dynamical properties

2.5.1Density

Density is defined as the weight of a unit volume of the fuel is an important property of the biodiesel. Fuel injection equipment that operates on volume metering system is sensitive to density of the fuel. In case of Biodiesel, Blended fuels and Additive mixed blended fuels, slightly higher mass of fuel has to be injected compared to petroleum diesel due to their higher density [8].

The densities (ρ) of Biodiesel, Blended fuels and Additive mixed blended fuels have been measured using a single stem pycnometer (pyrex glass) of bulb capacity of 12×10^{-3} dm^3 having a graduated stem with 5×10^{-7} dm^3 division. All density measurements have been performed in triplicate with the pycnometer[9]. The weighing has been done by using a high precision AND electronic balance (model HR 300, Japan) with a precision of ± 0.1mg. The reproducibility of density measurements is $\pm\ 2.8\times10^{-4}$ $g\cdot cm^{-3}$. The pycnometer with test solution has been allowed to stand for about 30 minutes in the thermostatic water bath so as to minimize thermal fluctuations. The temperatures of the solutions have been maintained to an uncertainty of ±0.01 K in an electronically controlled thermostatic water bath (Eurotherm, INSIN Private Ltd, Chennai). The density values of Biodiesel, Blended fuels and Additive mixed blended fuels have been measured at 15^0C to compare with Indian standards and are reported in Table-1 and Table 2. The experimentally measured density values are within Indian Standards thereby indicates that the fuels can be used in diesel engines without any modifications.

2.5.2Viscosity

Viscosity is the measure of internal friction of the fuel to its flow. Viscosity of the fuel influences the fuel injection process and atomization of the fuel [8]. Biodiesel generally has higher viscosity than petroleum diesel. Furthermore, viscosity is very sensitive to engine performance and in cases where the values are higher than the petro diesel then it leads to poor atomization of the fuel, incomplete combustion, chocking of the injectors and ring carbonization [10, 11].Thus blending of biodiesel with petrodiesel is favoured to be used as fuel in Diesel engines without any modifications.

Viscosity of the Biodiesel, Blended fuels and Additive mixed blended fuels have been measured with suspended level Ubbelohde viscometer [12] with a flow time of 186 s for distilled water at 303.15 K. The flow time has been measured by a digital stop watch capable of registering time accurate to ± 0.01 s. An average of three sets of flow times for each solution is taken for the purpose of the calculation of viscosity. The overall experimental reproducibility is estimated to be within $\pm\ 2\times10^{-3}$ m.Pa.s. The viscometer filled with test solution has been allowed to stand for about 30 minutes in the thermostatic water bath so as to minimize thermal fluctuations. The temperatures of the solutions have been maintained to an uncertainty of ±0.01 K in an electronically controlled thermostatic water bath (Eurotherm, INSIN Private Ltd, Chennai). The viscosities of the Biodiesel, Blended fuels and Additive mixed blended fuels have been measured at 40^0C to compare with Indian Standards and are reported in Tables .1 and 2. It is clear that the experimentally measured viscosity is within Indian Standards and ASTM Standards thereby approves the applicability of these fuels in Diesel engines.

2.5.3 Flash Point

Heat of combustion is an important engine parameter that measures the energy content in a fuel. Flash point is a measure of the temperature to which a fuel must be heated such that a mixture of the vapour and air above the fuel can be ignited. The petro diesel have high flashpoint (54^0C minimum; 71^0C being typical values. The flash point of neat biodiesel is typically greater than 93^0C [13]. As the biodiesel shows higher flash point comparing to petro diesel, it is considered as nonhazardous fuel.

The flash point of the Biodiesel, Blended fuels and Additive mixed blended fuels have been measured by Cleveland open cup apparatus. The sample has been poured in to a cup in the Cleveland open cup apparatus up to the marking present in the cup. The sample in the cup has been heated using an electric heater and the temperature of the sample has been measured using a thermometer capable of measuring temperature up to 300^o C with a resolution of $\pm 2^0$C. At fixed interval of temperature rise a small gap is opened on the lid and a flame is projected over the gap. At the flash point temperature, a flash appeared over the gap on the lid. The experiments have been repeated thrice and the average values of the flash point of the samples are reported in Table- 1 and Table 2. The experimentally measured Flash Point values satisfy the recommended Indian and ASTM Standards.

2.5.4Calorific value

Calorific value is another fuel property which measure the energy content in a fuel viz it has a direct correlation with the efficiency of the fuel. Calorific value of the biodiesel produced from waste cooking oil has been measured using the bomb calorimeter. Initially the calorimeter constant has been determined using benzoic acid as fuel. Then 1 gram of biodiesel fuel has been filled in a small cup inside the bomb. Oxygen at sufficient pressure has filled inside the bomb using a pressure regulator. The bomb has been placed inside a vessel containing 2 liters of water. Then the sample (Biodiesel, Blended fuels and Additive mixed blended fuels) has been made to burn inside the bomb using a spark created by electrical short circuit. The temperature rise of the water surrounding the bomb has been measured using a digital thermometer. The calorific value of the sample l fuel has been determined using the temperature rise of the water and calorimeter constant and are given in Table 1 and Table 2.The calorific values of the Biodiesel, Blended fuels and Additive mixed blended fuels are lower than that of petro diesel because of their oxygen content [14].The presence of oxygen in the studied samples may help for complete combustion of fuel in diesel engine.

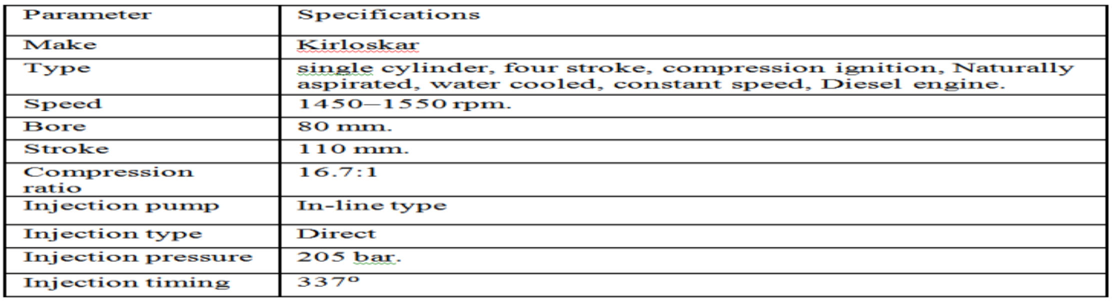
Table1: Physical and Thermo dynamical parameters of Diesel and Blended fuels

Combination	Diesel	B5 + D95	B10+ D90	B15+D85	B20 +D80	B25+ D75	B100	Standards	
								IS15607:2005	ASTM
Density (Kg/m^3)	825.3	828.2	830.8	834.4	836.5	839.1	876.4	860-900	860-900 D4052
Viscosity (mm^2/s)	2.232	2.331	2.454	2.549	2.653	2.772	4.654	2.5-6.0	1.9-6.0 D6751
Flash point (°C)	59	61	63	66	71	74	193	120^0C min	130^0Cmin D6751
Lower heating value (KJ/Kg)	43053.5	42858.9	42469.5	42080.2	41690.8	41465.7	36044.9	NA	**NA**

Table 2: Physical and Thermo dynamical parameters of Diesel and Additive (DEE) mixed blended fuels

Combination	Diesel	DEE	B20 +D80	B20+A5+D75	B20+A10+D70	B20+A15+D65	Standards	
							IS15607:2005	ASTM
Density (Kg/m3)	825.3	713.4	836.5	831.2	824.4	814.8	860-900	860-900 D4052
Viscosity (mm2/s)	2.232	0.223	2.653	2.616	2.521	2.418	2.5-6.0	1.9-6.0 D6751
Flash point (°C)	59	--	71	58	54	49	120^0C min	130^0Cmin D6751
Lower heating value (KJ/Kg)	43053.58	33892.12	41690.78	41301.41	40912.04	40522.66	NA	NA

Table 3: Engine Specification



Parameter	Specifications
Make	Kirloskar
Type	single cylinder, four stroke, compression ignition, Naturally aspirated, water cooled, constant speed, Diesel engine.
Speed	1450—1550 rpm.
Bore	80 mm.
Stroke	110 mm.
Compression ratio	16.7:1
Injection pump	In-line type
Injection type	Direct
Injection pressure	205 bar.
Injection timing	337°

Table 4: Pressure Sensor Specification

Parameter	Specification
Pressure range	0 to 100 bar
Sensitivity	40 mv/bar
Linearity	≤ ± 1% FSO

2.6 Computerized Diesel engine experimental setup and procedures

Computer interfaced diesel engine (see fig 2) test bed purchased from Legion brothers; Bangalore has been used for performance testing. The specifications of the test engine have been given in the Table 3 and Table 4. Eddy current dynamometer has been used to load the engine through a computer. A maximum to 10 Kg load could be applied by the dynamometer. Torque at the dynamometer is measured using a load cell transmitter. A non contact PNP sensor (see table 4) is used to measure the engine RPM. Kistler make piezoelectric sensor is used to measure the cylinder pressure. The sensor is connected to the charge amplifier robust integrated high temperature viton cable. The specifications of the sensor are given in table 4. The crank angle is measured using the crank angle encoder. Shell and tube type exhaust gas calorimeter is measured the heat carried away by the engine exhaust gas. Water flow to the exhaust gas calorimeter is measured using rotameter. Mass air flow sensor is used to measure the air flow rate; it consists of wire suspended in the engine's air stream. The amount of current required to maintain the wire's resistance is directly proportional to the mass of air flowing past the wire. The integrated electronic circuit converts the measurement of current in to the voltage signal and sends to the computer to calculate air flow rate. The fuel consumption measurement system consists of a burette fitted with two optical sensors, one at high level and the other at lower level. The time taken for the fixed volume of fuel in the burette to pass through the two optical sensors has been used to calculate the rate of fuel consumption. K type thermocouples have been used to measure the temperature of engine exhaust, calorimeter inlet water and calorimeter outlet water. Data acquisition system and software to process the data are supplied with the test rig.

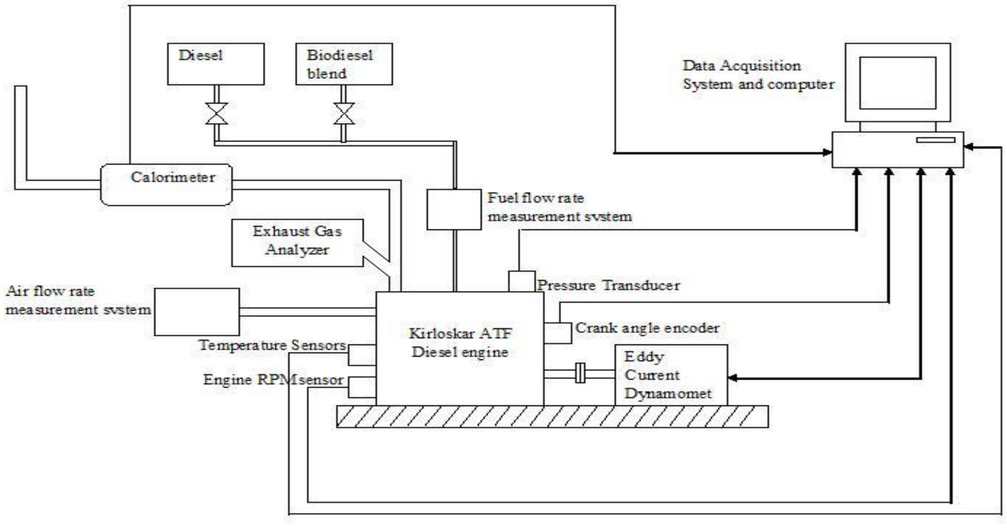


Fig 2. Schematic diagram of the experiment setup

III. RESULTS AND DISCUSSION

The biodiesel has been produced from waste cooking oil using the transesterification process as described above and the physico thermo dynamical properties of biodiesel experimentally measured and reported in Table 1.It is seen from table, these values are within Indian & ASTM standards indicating its applicability of the biodiesel as alternative fuel in Diesel engine. Further necessary blended fuels B5, B10, B15, B20 and B25 are prepared by adding appropriate quantity of biodiesel with petrodiesel. Similarly the additive diethyl ether was also added in appropriate quantities to prepare mixed blended fuels namely B20A5, B20A10 and B20A15 respectively. For the above blended fuels as well as the additive mixed blended fuels, the density, viscosity, flash point and calorific values have been experimentally measured with the standard instruments described earlier and the values are given in Tables 1 & 2. It is clear from the Tables 1 & 2, the measured values reported are within Indian and ASTM standards indicating the applicability of the fuels in the existing Diesel engines.

3.1 Brake specific fuel consumption

Brake specific fuel consumption is the ratio between mass fuel consumption and brake effective power and for a given fuel; it is inversely proportional to thermal efficiency. Brake specific fuel consumptions have shown no significant variation with composition of biodiesel blends at a particular load (Fig 3). For all the fuels tested the brake specific fuel consumptions decreased with increase in load. One possible explanation for this trend may be attributed to the higher percentage of increase in brake power with load as compared to fuel consumption [15]. However with increase of load BSFC decreases. Similarly the addition of additive has shown little changes in the BFSC values.(Fig 4). Silva etal [16] reported similar insignificant changes in BSFC, when tested with sunflower oil-biodiesel blends. Similarly Dorado et al [17] while testing a 3 cylinder 2.51 engine with pure biodiesel from waste olive oil also reported insignificant differences in BSFC with diesel fuel.

3.2 Terms in graphs

- B100 – 100% Waste cooking oil Methyl ester
- DEE – Di Ethyl Ether
- B5 + D95 – 5% Waste cooking oil Methyl ester + 95% Diesel
- B10 + D90 – 10% Waste cooking oil methyl ester + 90% Diesel
- B15 + D85 – 15% Waste cooking oil methyl ester + 85% Diesel
- B20 + D80 – 20% Waste cooking oil methyl ester + 80% Diesel
- B25 + D75 – 25% Waste cooking oil methyl ester + 75% Diesel
- B20+A5 + D75 – 20% Waste cooking oil methyl ester +5% Additives +75% Diesel
- B20+A10 + D70 – 20% Waste cooking oil methyl ester+10% Additives + 70% Diesel
- B20+A15 + D65 – 20% Waste cooking oil methyl ester +15% Additives+ 65% Diesel

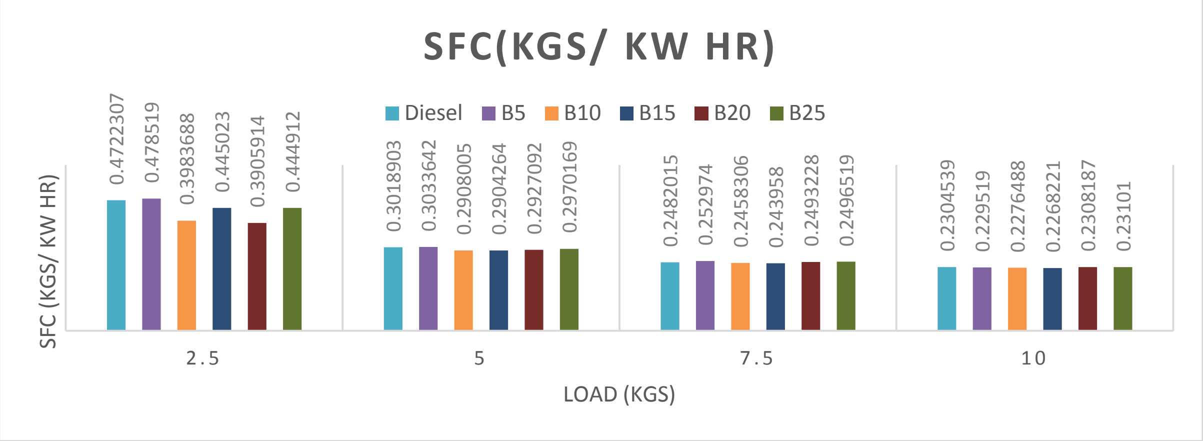


Fig 3. Effect of Load on Specific Fuel Consumption (kg / kW hr) of Diesel and Biodiesel blends

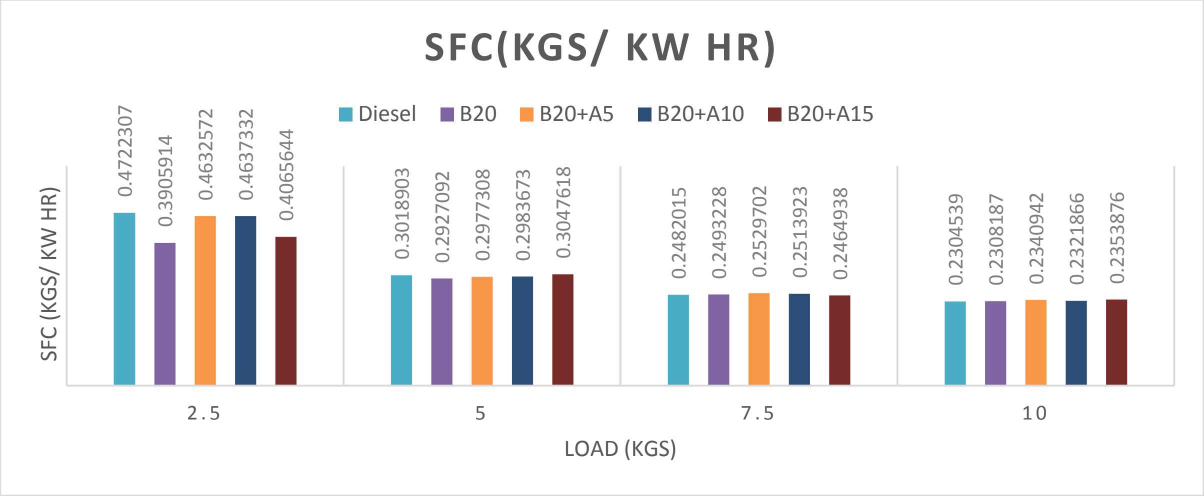


Fig 4. Effect of Load on Specific Fuel Consumption (kg / kW hr) of Diesel and Additive mixed blended fuels

3.3 Brake Thermal Efficiency

Thermal efficiency is the ratio between the Mechanical power output and the Thermal energy introduced through fuel injection. The energy introduced through fuel injection is the product of injected fuel mass flow rate and lower heating value. Thus the inverse of thermal efficiency is often termed as brake specific energy consumption and hence this parameter gives better idea regarding the performance of an engine with different fuels.

BTE increases with load in all cases (Fig 5).This may be due to the reduction in heat loss and increase in power with increase in percent load.

BTE increases with the percentage of blend of biodiesel at a particular load (see fig 3). At the maximum load, the efficiencies of B5, B10, B15, B20 and B25 are 0.88 %, 2.64%, 3.97%, 3.11%, and 3.99%, respectively, higher than the case of petrodiesel. Similarly in the case of additive (Fig 6) , the Brake Thermal efficiencies of B20+A5, B20+A10 & B20+A15 are 2.62 %. 4.46 % and 4.02% higher than base petrodiesel efficiency. The increased thermal efficiency may be attributed to the reductions in friction loss associated with higher lubricity.

The slight variations of brake thermal efficiency with biodiesel blends and additives may also be attributed to spray characteristics, higher viscosity and lower calorific values.

Labeckas and slavinskas [18], Ramadhas etal [19] also reported higher thermal efficiencies with blended bio diesel fuels, in comparison to petrodiesel and accounted the improved efficiency with increase in lubricity of blended fuels.

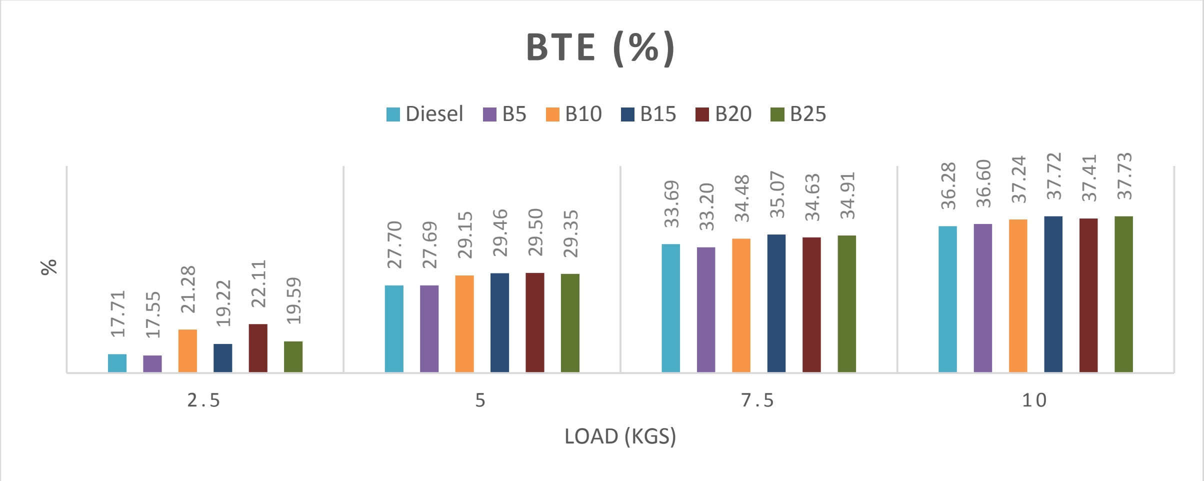


Fig 5. Effect of Load on Brake Thermal Efficiency of Diesel and Biodiesel blends

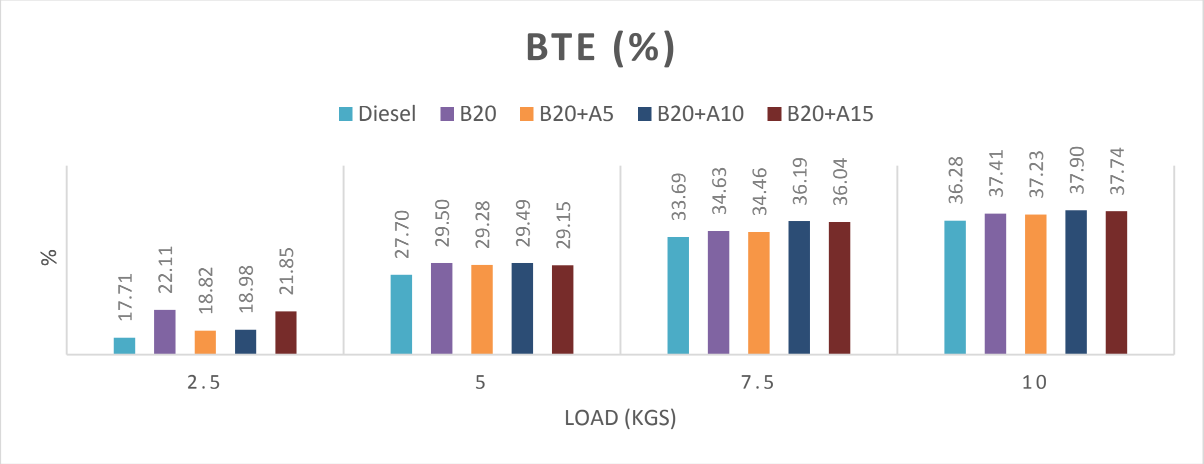


Fig 6. Effect of Load on Brake Thermal Efficiency of Diesel and Additive mixed blended fuels.

3.4 The Maximum cylinder Pressure

It depends on the burned fuel fraction during the premixed burning phase i.e. the initial stage of combustion. The cylinder pressure characterizes the ability of the fuel to mix well with air and burn. It is seen that that peak pressure increases as engine load increases. (Figures 7 & 8). However, the peak pressure decreases with increase in concentration of biodiesel as well as additive. But at higher loads the peak pressure for diesel is higher than the blended fuel cases. The variation of Maximum cylinder pressure for blended biodiesel and Additive cases may be attributed to the higher cetane numbers in comparison to petrodiesel which may results in shorter ignition delay and more fuel burnt in diffusion stage. A similar argument was advanced by B. S. Chauhan etal for this study on a diesel engine fuelled with Jatropha biodiesel oil and its blends [20].

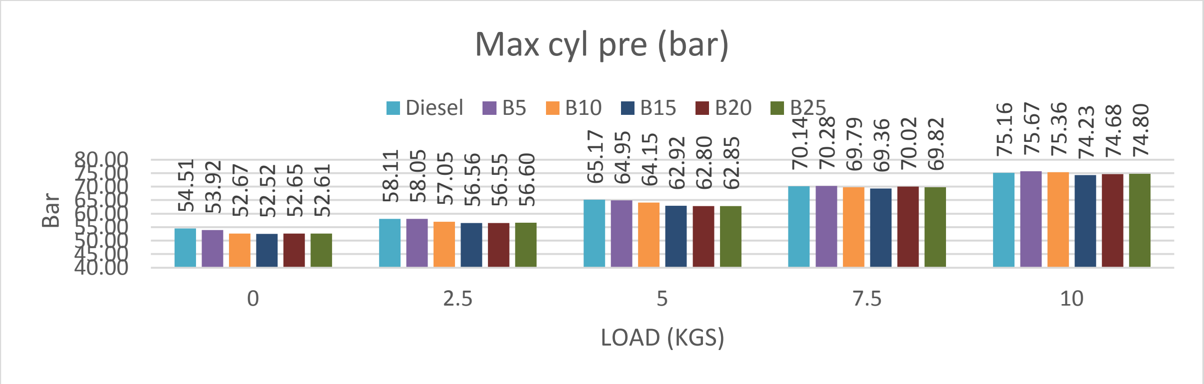


Fig 7. Effect of Load on Maximum cylinder pressure (bar) of Diesel and Biodiesel blends

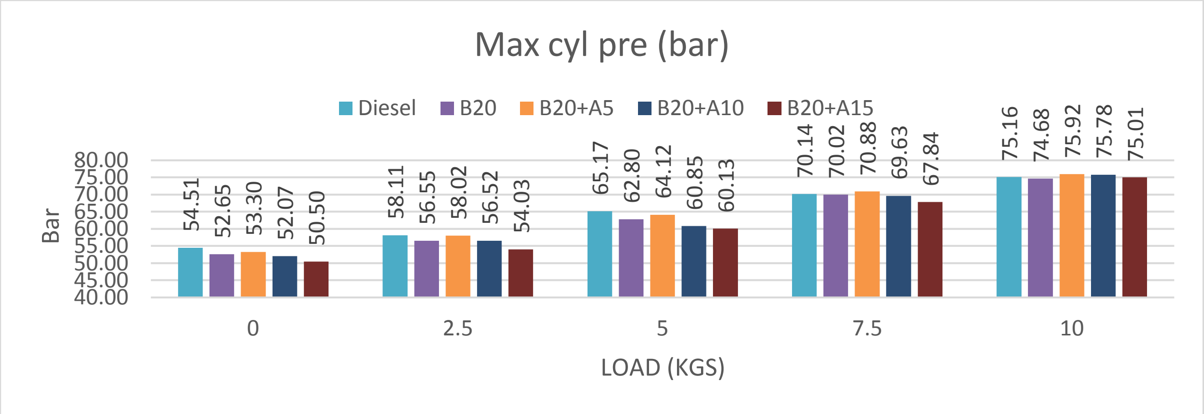


Fig 8. Effect of Load on Maximum cylinder pressure (bar) of Diesel and Additive mixed blended fuels

3.5 Ignition Delay

Ignition delay in a diesel engine is defined as the time between the start of fuel injection and the onset of combustion. The values of ignition delay for pure diesel, blended biodiesels and additives are given in figures 9 & 10 respectively. It is seen from figures 9 & 10 with the increase of load the ignition delay decreases. At the maximum load the ignition delay for blended fuels as well as for additives are lower than the case of pure petrodiesel. Similar reports are available in literature [21]. The possible reason for advance of ignition delay may attributed to the biodiesel's higher Surface tension values as well higher Surface tension values of biodiesel blends with additive in comparison to pure petrodiesel since higher surface tension contributes to an advance in injection timing; its influence on ignition delay is complex due to competing interactions with atomization, penetration, droplet size and evaporation [22]. Furthermore, the start of fuel injection is generally advanced for biodiesel due to the differences in density, bulk modulus of compressibility and speed of sound values for biodiesel when compared to diesel [23, 24] and thereby reducing the ignition delay. Biodiesel (oxygenated fuel) has lower compressibility and hence higher bulk modulus partly due to the presence of oxygen in the fuel structure which creates a permanent dipole moment in the molecule resulting in stronger bonding and increased molecular affinity compared to pure diesel (hydrocarbon). Furthermore, structure rigidity and intermolecular forces that dictate the free space between molecules are believed to influence bulk modulus [25, 26]. These factors reduce the free space between molecules in biodiesel and hence the intermolecular free length and increase the bulk modulus relative to diesel [27]. Furthermore, biodiesel has a higher cetane number than diesel which also results in shorter ignition delay [28]. Atomization, air fuel mixture formation, spray penetration and spray cone angle depend upon viscosity of the fuel. Viscosity of the fuel affects ignition and hence ignition delay also. The above physico thermal parameters may be reasons for the variations of Ignition delay for the systems reported in the work. The addition of additive concentration increases the ignition delay at all loads in comparison to B20 fuel.

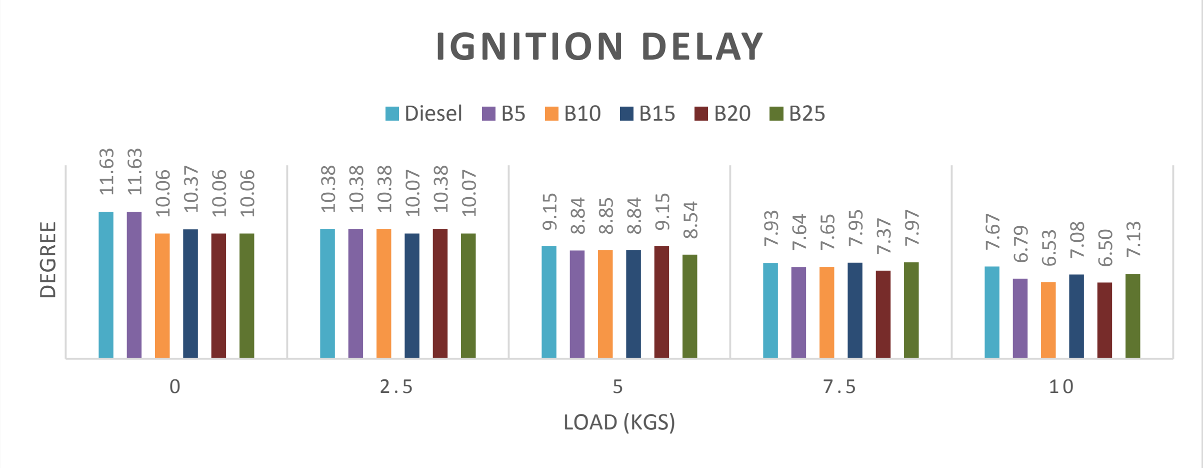


Fig 9. Effect of Load on Ignition delay (deg) of Diesel, Biodiesel blends and Biodiesel

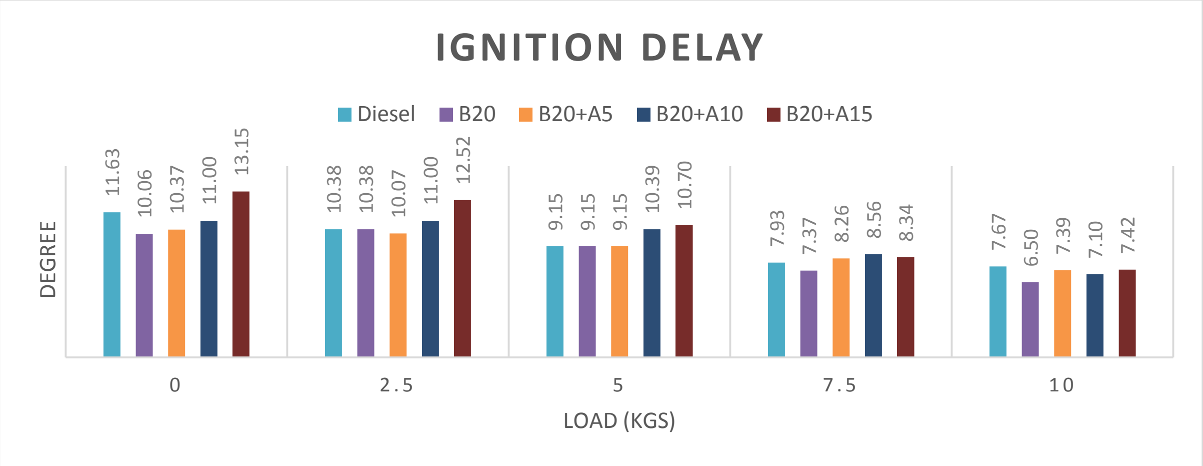


Fig 10. Effect of Load on Ignition delay (deg) of Diesel and Additive mixed blended fuels.

IV. CONCLUSION

This paper highlights the performance and combustion of a single cylinder four stroke diesel engines operated on blends of biodiesel produced from waste cooking oil. An additive Diethyl ether (DEE) has been added in three different proportions to B20 blended fuel to study the effect of additive on the performance and combustion of the diesel engine. The study yields the following results

- The thermal efficiencies of the diesel engine show an increasing trend with both blended fuels and additive mixed blended fuels which may be attributed to the increase in lubricity.
- The specific fuel consumption shows insignificant changes with both blended fuels and additive mixed blended fuels.
- The ignition delay starts earlier for both blended fuels and additive mixed blended fuels that may be attributed to the values of density, bulk modulus of compressibility, speed of sound and surface tension of these fuels.
- The Maximum cylinder pressure for both blended fuels and additive mixed blended fuels are lower than the petro diesel which may be attributed to the cetane number of the blended fuels and additive mixed blended fuels.

Acknowledgement

The authors wishes to express their sincere gratitude to the undergraduate students A. Jegadheesan, R. Raja and S. Ramajeyam in the collection of waste cooking oil and in the preparation of biodiesel

REFERENCES

[1] IEA, International Energy Agency. *World energy Outlook* 2009. Paris: OECD/ IEA; 2009.

[2] C.Adhikesavan,K.Rajagopal,G.Johnson Newton and J.Selwin Rajadurai Poc of International conferences ICEA 2013,held at Sardar Raja College of Engg.Alangulam 627803 on april 3, 2013, 155-158.

[3] K.Rajagopal, G. Johnson Newton, J. Selwin Rajadurai and c.Adhikesavan. *Bloomsbury publications pvt.Ltd*. Newdelhi.ISBN 978-93-82563-48—8. 2013, 367-373.

[4] K.Rajagopal, J. Johnson , J. Selwin Rajadurai, Production of biodiesel from waste used cooking oil using two different alkaline catalyst, *International journal of chem. Tech Research*. (submitted)

[5]. Subramanian, K. and Ramesh, A., "Use of Diethyl Ether Along with Water-Diesel Emulsion in a Di Diesel Engine," *SAE Technical Paper* **2002**-*01-2720*, **2002**.

[6]. Murugesan A, Umarani C, Chinnusamy TR, Krishnan M, Subramanian R, Neduzchezhain N (2009). Production and analysis of bio-diesel from non-edible oils-A review. *Ren. Sust. Energy Rev. (13*), 2009, 825-834.

[7]. Keera .S.T, El sabagh.S.M, Taman.A.R Transesterification of vegetable oil to biodiesel fuel using alkaline catalyst. *Fuel (90)* 1, 2009, 42-47.

[8]. Demirbas A (2008). Biodiesel from waste cooking oil via base-catalytic and supercritical methanol transesterification. *Energy Convers. Manage. (50),* 2008, 923-927.

[9]. Dr. K. Rajagopal, J. Johnson, Studies on volumetric and viscometric properties of l- histidine in aqueous xylose solution over temperature range (298.15 to 313.15) K., *International Journal of Chem. Tech Research (7),* 2015.

[10]. Barsin et al, Performance and emission characteristics of a naturally aspirated diesel engine with vegetable oil fuels SAE 810955, 1995

[11]. IP standards for analysis and testing of petroleum products, vol 1 and 2 London: inst. Per.1990

[12]. Rajagopal.K and Jeyabalakrishnan .S.S, Effect of temperature on volumetric and viscometric properties of homologous amino acids in aqueous solutions of Metformin hydrochloride. *Chinese .J.chemical Engineering (18),* 2010, 425-445.

[13]. D. Baj Pai and V. R. Thygi J Biodiesel :Source, Production, composition, properties and its benefits. *.Oleo Sci (55)10*, 2006, 487-502.

[14]. P. K. Sahoo, L. M .Das, Combustion analysis of Jatropha, Karanja and Polanga based biodiesel as fuel in a diesel engine, *Fuel (88),* 2009, 994-999.

[15] H. Raheman And A. R. Phadatare *Biomass and Bio energy (27),* 2004, 393-397.

[16] Silva. F. N, Prata. A. S, Teixeira. J. R. Technical feasibility assessment of oleic sunflower methyl ester utilizations in diesel bus engines. *Energy Convers. manage (44),*2005, 2857–2878.

[17] M. P. Dorado, E. Ballesteros, J. M. Arnal, J. Gomez and F. Hopez, Exhaust emission from diesel engine fuelled with transesterification waste olive oil. *Fuel (82),* 2003, 1311–1315.

[18]. G. Labeckas and S.Slavinskas blended fuels , *Energy conversion management (47),* 2006, 1954-1967.

[19]. A. S. Ramadhas, c. Muraleedharan , C. Jeyaraj *Renewable Energy (20),* 2005, 1789-1800.

[20] Chauhan BS, Kumar N, Cho HM. A study on the performance and emission of a diesel engine fueled with Jatropha biodiesel oil and its blends. *Energy (37)1*, 2012, 616-622.

[21]. John B Heywood. *Thermochemistry of fuel air mixture in Internal Combustion Engine Fundamentals*. (Ist ed New York: McGraw-Hill Inc, 1988), 62-96.

[22]. J. Sun, J. A. Caton, T. J. Jacobs, Oxides of nitrogen emissions from biodiesl- fuelled diesel engines, *Prog.in Energy and Combusion Science,3(6),* 2010, 677-695.

[23]. Canakci M, Van Gerpen JH. Comparison of engine performance and emissions for petroleum fuel, yellow grease biodiesel and soybean oil biodiesel. Paper presented at *ASAE Annual international meeting*; 2001 Jul 30 – Aug 1; Sacramento, California, USA.

[24]. Lu X, Ge Y, Wu S, Han X. An experimental investigation on combustion and emission characteristics of turbo charged DI engines fueled with blends of biodiesel. Paper presented at the *SAE fuels and lubricants meeting*; 2005 May;Rio de Janeiro, Brazil.

[25]. Cutler GW, Mc Mickle HR, Webb W, Schiessler WR. Study of the compressions of several high molecular weight hydrocarbons. *J Chem Phys 29(4),* 1958, 727-740.

[26]. Rolling R, Vogt C. The adiabatic bulk modulus of normal paraffin hydrocarbon from hexane to hexadecane. *J Basic Eng, (82),* 1960, 635-644.

[27]. Szybist JP, Kirby SR, Boehman AL. NOx emissions of alternative diesel fuels; a comparative analysis of biodiesel and FT diesel. *Energ Fuels (82),* 2005, 1484-1492.

[28]. Sinha S, Agarwal AK. Experimental investigation of the combustion characteristics of a biodiesel (rice-bran oil methyl ester)-fuelled direct-injection transportation diesel engine. *P I Mech Eng D-J Aut 221(8),* 2007, 921-932.