An Effect of Injection Timing on Di Diesel Engine Powered By Algae Methyl Ester

R. Velappan
Assistant Professor, Department of Mechanical Engineering
Annamalai University
Annamalainagar, India

S. Sivaprakasam
Associate Professor, Department of Mechanical Engineering
Annamalai University
Annamalainagar, India

***Abstract*—The rapid depletion of petroleum fuels and their ever increasing costs have lead to an intensive search for alternate fuels. This study mainly focused on the collection of bio-fuel from algae chlorella vulgaris to run the diesel engine. Using soxhlet chemical extraction method 85% of algae oil obtained and transesterification process was also carried out. The algal oil was converted in to algae methyl ester. The blending was carried out with pure diesel with proportion of 20%. The combustion parameters were also analysed with various advanced in injection timing like 21º, 22 º and 23º bTDC rated crank angles in degree. This research work is focused on the experimental investigation of the effect of injection timings with an advanced in crank angle degrees. The emission reduction was observed for NOx, CO, and smoke with advanced injection timing and also increased Brake Thermal Efficiency (BTE). The optimal injection timing was found in 22 º crank angle degree for the optimal performance and combustion of the engine.**

Keywords*— Biodiesel, Algae oil, Diesel, Transesterification, Injection timing. Introduction

I. Introduction

The rapid depletion of petroleum fuels and their ever increasing costs have lead to an intensive search for alternate fuels. It has been found that the vegetable oils are promising substitute, because of their properties are similar to those of diesel fuel and they are renewable and can be easily produced [1, 2]. Rudolph Diesel, the inventor of the diesel engine that bears his name, experimented with fuels ranging from powdered coal to peanut oil. Several researchers experimented the use of vegetable oils as fuel on diesel engine and reported that the performance was poor, citing the problems of high viscosity, low volatility and their poly-unsaturated character [3]. Experiments were conducted on preheated vegetable oils temperatures at which viscosity of the vegetable oils were matched to that of diesel fuel. It was reported that preheated vegetable oils decreased pollution levels of smoke and NOx emissions [4]. The problems of crude vegetable oils can be solved, if these oils are chemically modified to bio-diesel. Bio-diesels derived from vegetable oils present a very promising alternative to diesel fuel since biodiesels have numerous advantages compared to fossil fuels as they are renewable, biodegradable, provide energy security and foreign exchange savings besides addressing environmental concerns and socio-economic issues. The use of fossil fuels in various industries, such as transportation, has been reported to be one of the main factors causing high CO_2 levels in the atmosphere which is resulting in global warming [5, 6]. Research into the use of biodiesel in Compression Ignition (CI) engines has recently increased due to the depletion of fossil fuels, high fuel prices and pollution problems associated with exhaust gas emissions. Developing alternative fuels is an essential step towards solving the problems associated with fossil fuels [7]. It is important that alternative fuels be renewable, have less impact on the environment and be produced and used by currently available technology. The natural biodiesel resources such as oil crops and waste cooking oil are not sufficient to cover the global transportation fuel demand. Therefore, exploring other potential sources for alternative fuels is a necessity. Microalgae are regarded as a promising alternative fuel for IC engines. Microalgae are unicellular photosynthetic organisms that use light energy and carbon dioxide (CO_2), with relatively higher photosynthetic efficiency [8].

Chlorella vulgaris algae are unicellular and from 5 to 10 μm in size. Chlorella vulgaris is one of the most studied and researched of all algae as a resource for replacing fossil fuels. Chlorella vulgaris algae contain considerable amount of lipids that are used to produce renewable and "carbon free energy" in the form of Biodiesel [9,10]. Lipids can be also transformed into other fuels like gas, jet fuel, etc. After lipids extraction the remaining part of algae biomass represents a valuable food additive for fish, cutlery and chicken largely used in farming [11]. Combination of bio-fuel production with the sale of the remaining biomass makes this business profitable. Experiments were carried out with bio-diesel on direct injection diesel engine. It was reported from their investigations that biodiesel operation decreased smoke emissions and increased NOx emissions in comparison with pure diesel operation.

II. Materials And Methods

The Chlorella vulgaris alga was selected as the source of material for biodiesel, which is having high lipid content of up to 55%. It was cultivated in the open pond method. After 24 days of growth, the species were harvested and dried in the shadow for few days. Then the collected species were crushed and powdered. N-hexane and iso-proponal was used as solvent in the ratio of 1:2 in Soxhlet solvent apparatus for the extraction of algae lipid. 400 ml of lipid was extracted from 1.2 kilogram of algae. Maintaining the temperature of 65ºC in the evaporator, the solvent and lipid was separated. Transesterification method was chosen to extract the biodiesel from the algae oil. In this method, 20 ml of methanol, 1.5 gm of potassium hydroxide was added with one liter of algae oil in the reactor. The reaction was conducted for one hour at 60ºC at 110 rpm. Then it is filtered by using Buckner funnel, finally the bottom layer glycerine was separated. In order to obtain the crude biodiesel, it was necessary to remove solvent by distillation. The algae methyl ester (AME) extracted from algae was blended with neat diesel fuel in the ratio of 20% AME with 80% of diesel fuel (AME20). The important properties of the AME 20 was compared with that of the sole diesel fuel and listed in Table 1

TABLE I. PROPERTIES OF DIESEL AND BIODIESEL

Property	Diesel	AME
Viscosity @40ºC in CSt	2.57	4.25
Flash Point inºC	65	113
Pour Point in ºC	-26	-15
Gross calorific value in MJ/kg	45.2	42.3
Density@15ºC in gm/cc	0.832	0.862
Hydrogen	1.452	1.721
Carbon	86.404	89.765
Nitrogen	0.281	0.0292

III. EXPERIMENTAL SETUP

The experimental investigations were conducted in a Kirloskar TV-I DI diesel engine. The specification of the test engine was given in table 2. A single cylinder 4-stroke water cooled diesel engine with 3.2 kW brake power at constant of 1500 rpm was used in this study. The engine was coupled to an eddy current dynamometer with control systems. The engine is equipped with crank angle sensor, piezo type cylinder pressure sensor, thermocouples to measure the temperature of the water, air and exhaust gas. Di-gas analyzer was used to measure the emissions from the exhaust gas. AVL smoke meter was used to the smoke density from the engine exhaust gas. The schematic view of the experimental setup was shown in the Fig. 1.

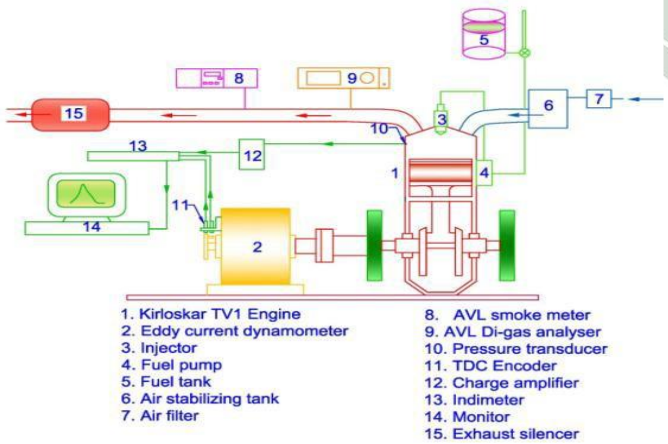

Fig. 1. Schematic view of experimental setup.

TABLE II. ENGINE SPECIFICATIONS

Type	Vertical, water cooled, four stroke
Number of cylinders	One
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5:1
Maximum power	5.2 kW
Speed	1500 rev/min
Dynamometer	Eddy current
Injection timing	23 (before TDC)
Injection pressure	250 kgf/cm^2

IV. RESULTS AND DISCUSSION

The experiment is carried out in the single cylinder, four stroke, water cooled diesel engine. The experiment is conducted with neat diesel fuel and with algae methyl ester blend (B20) with various injection timings such as 21º, 22º and 23º crank angle bTDC.

A. Brakethermal efficiency

Thermal efficiency is the true indication that the efficiency with the chemical energy input in the form of fuel is converted into useful work. Fig. 2 shows the effect of brake power on brake thermal efficiency. It is seen from the graph, when load increases brake thermal efficiency also gradually increases. From the figure, it is revealed that the brake thermal efficiency of the CA 21° bTDC for blend of the B20 was lesser than that of the diesel fuel. The brake thermal efficiency for diesel fuel for CA 21° bTDC at the maximum load is 26.48%, whereas for the CA 22° bTDC the brake thermal efficiency of diesel in maximum load is 27.48%. The brake thermal efficiency for diesel fuel at CA 22º is 27.48% and B20 is 27.68% at the maximum load. From the figure, it was clear that the B20 having 2% higher thermal efficiency when compared with conventional diesel fuel at CA 22º bTDC. The advanced injection timing CA 22º shows higher brake thermal efficiency compared to at CA 22º and at CA 23º bTDC (standard). It is because of the longer ignition delay and proper atomisation of the fuel.

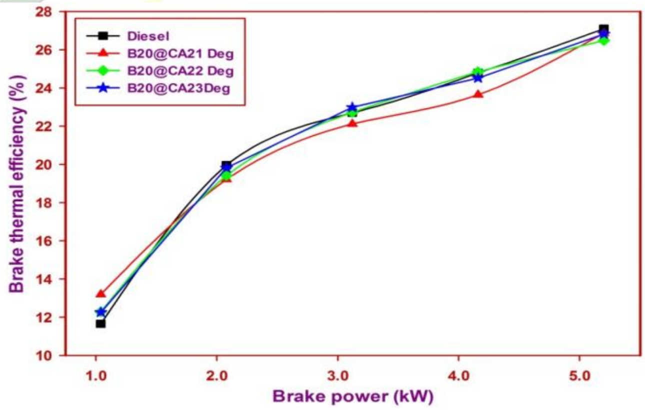

Fig. 2. Brake power against brake thermal efficiency.

B. Smoke density

Smoke density is generally correlated with soot formation and is associated with low combustion temperature and with incomplete combustion in the combustion cylinder. The variation of the smoke density with brake power is presented in figure 3. The smoke density increases with an increase in engine loads. Because of the amount of fuel per unit time increases as load increases and consequently smoke density increases. It is seen from the graph, that the smoke density level for diesel is 66.49 and for B20 blend of AME at maximum load 71.1 HSU at standard injection timing. The smoke opacity for B20 at full load for CA 21^o, CA 22^o and CA 23^o are 67.4 HSU, 70.3 HSU and 71.1 HSU, respectively. This is due to heavy molecular structure of AME blend (B20) and also because of higher viscosity and density.

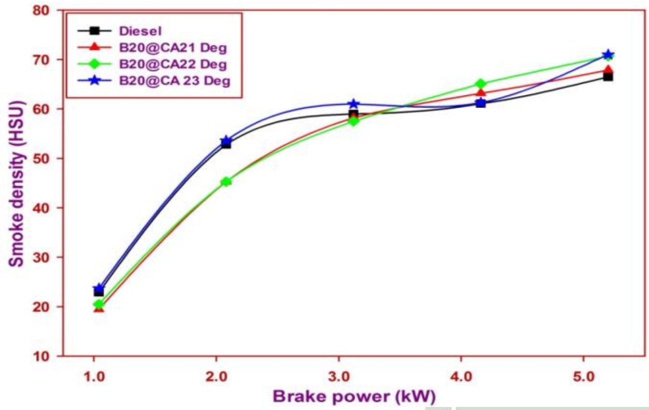

Fig. 3. Brake power against smoke density.

C. Carbonmonoxide (CO)

The variation of carbon monoxide emission with brake power is shown in figure 4. Carbon monoxide emission is mainly due to fuel to air equivalence ratio and in-cylinder temperature. The carbon monoxide emission of diesel fuel, varied from 0.15 % of vol. to 0.18 % of vol. at different load conditions at CA 23^o bTDC (standard). From the graph, it is clear that the CO emission is found higher 30% of vol. for B20 when compared with neat diesel at standard injection timing. The CO emission of B20 at CA 21^o is 0.11 % of vol. and it was 0.12 % of vol. for the same blend at CA 22^o. From the graph, it is revealed that CA 21^o emits lower CO emission, when compared with other crank angle degrees.

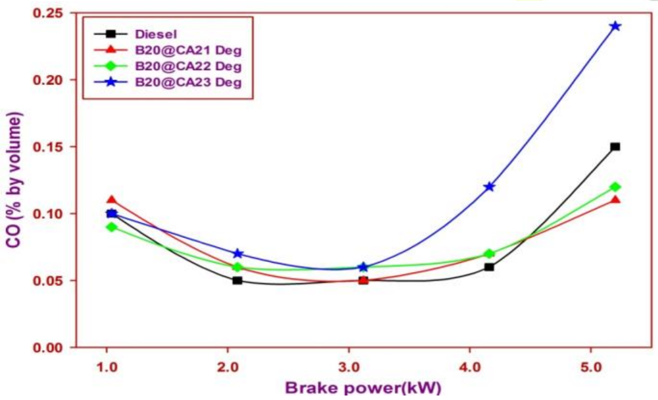

Fig. 4. Brake power against carbon monoxide.

D. Hydrocarbon (HC)

Hydrocarbon emission with respect to brake power for diesel and 20 % AME (B20) is shown in figure 5. Variation of hydrocarbon emission mainly depends on applied load and fuel composition. Hydrocarbon emission is generally because of the incomplete combustion of fuel. Hydrocarbon emission of diesel fuel varied from 57 ppm to 133 ppm for different loads at CA 23^o bTDC standard injection timing. The HC emissions for B20 are found lower than diesel at all loads and all injection timings. This is due to higher oxygen content present in the algae methyl ester and it oxidizes the hydrocarbons in to water and CO_2. The HC emission of B20 blend of AME at CA 21^o, CA 22^o and CA 23^o are 79 ppm, 93 ppm and 118 ppm, respectively.

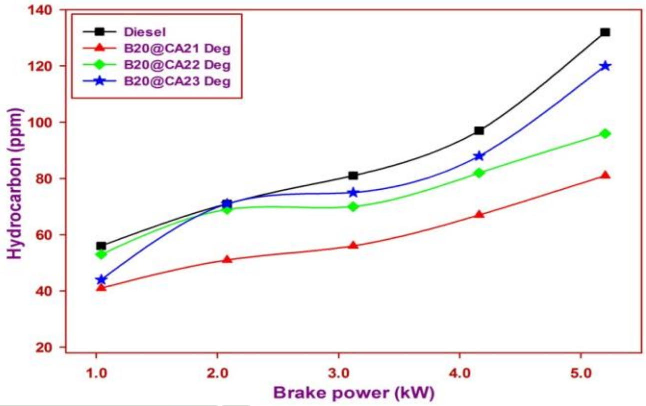

Fig. 5. Brake power against hydrocarbon emission.

E. Oxides of Nitrogen (NOx)

The variation of NOx emission with respect to brake power is shown in figure 6. From the figure, it is clear that the NOx emission of B20 blend of AME was similar to that of the diesel fuel at CA 23°. The NOx emission of B20 fuel is 704 ppm at CA 21^o, where as it is 753 ppm for CA 22^o. Even though the value of B20 fuel increased from CA 21^o to CA 22^o, further it was lesser than that of the diesel fuel. Due to prolonged ignition delay and reduced temperature during the combustion, the NOx emission was found minimum for B20 fuel blend at all injection timings at full load.

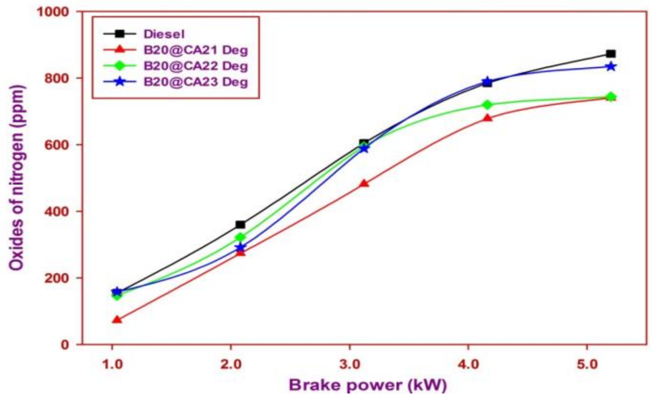

Fig. 6. Brake power against oxides of nitrogen.

F. Incylinder pressure

It can be seen from figure 7 that algae methyl ester blend (B20) had a 7.5% lower peak pressure than that of neat diesel at standard injection timing. The same trend is observed during the entire range of engine operation at no load and half load conditions for all injection timings. It is clear from Fig. 2 that the peak pressure for B20 is 65.7 bar occurring at CA 23^o bTDC, 66.5 bar occurring at CA 22^o bTDC, 66.2 bar occurring at CA 21^o bTDC, respectively.

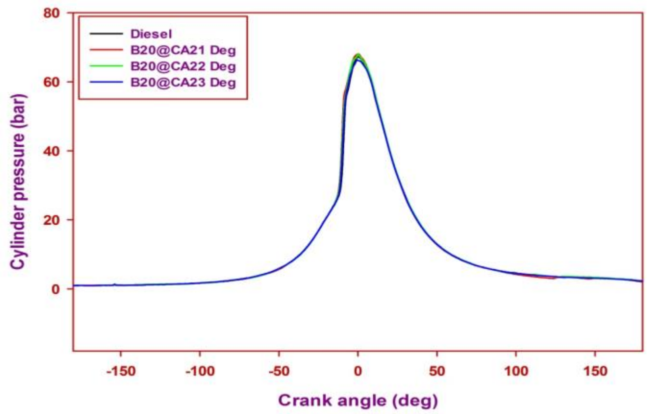

Fig. 7. In-cylinder pressure vs. crank angle.

G. Heat release rate

The heat release rate at selected operating points of different diesel–biodiesel blend fuels and neat diesel operation are also shown in figure 8. The heat release rate at no load and half load are also analyzed, which gives very significant information on the ignition delay in case of diesel and algae methyl ester blend (B20). While running with diesel at standard injection timing (23º CA bTDC), increased accumulation of fuel during the relatively shorter delay period resulted in higher rate of heat release. Because of the longer delay period, minimum heat release rate occurs earlier for algae methyl ester at different injection timings in comparison with neat diesel.

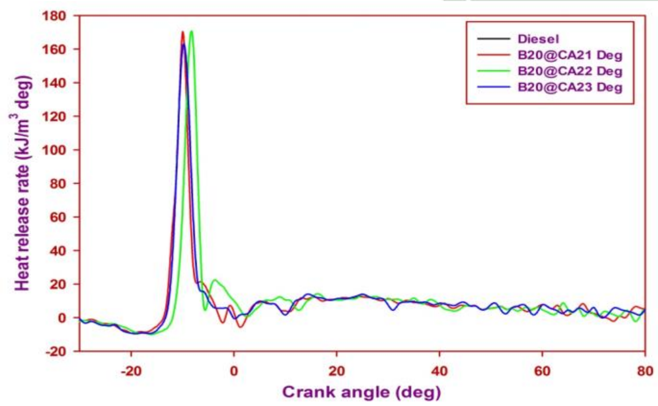

Fig. 8. Heat release rate vs. crank angle.

CONCLUSION

In the present investigation, Kirloskar TV 1 engine performance, emission and combustion characteristics by using algae fuel with various injection timing such as CA21˚, CA 22˚ and CA 23˚ crank angle are studied and compared the values with neat diesel. Following results can be concluded from the experimental study.

- The brake thermal efficiency for B20 at CA23˚ shows a minor increase compared to that of diesel fuel.
- Diesel fuel with advanced injection timing (CA 21˚) produce lesser smoke density compared to that of algae fuel at different parameters.
- The carbon monoxide for B20 blend fuel at standard injection timing (CA23º) shows the maximum reduction compared to that of all other injection parameters.
- At the standard injection timing CA23º, shows the highest reduction in the hydrocarbon emission.
- The oxides of nitrogen emission for neat diesel and B20 CA21º with injection timing of CA 21º shown the maximum reduction compare to that of all other parameters.
- It is concluded that neat algae methyl ester blend (B25) which results in minimum peak cylinder pressure at CA 23º bTDC injection timing. The ignition delays are consistently longer for B25 than diesel at all other injection timing parameters with the difference increasing with the load.

On the whole it is concluded the algae oil (B20) blend can be used as an alternative fuel in diesel engine. The change in the injection timing CA 21º shows the considerable change in the performance as well as emission characteristics.

REFERENCES

[1] Anand, K., Sharma, R.P. and Pramod S. Mehta. "A comprehensive approach for estimating thermo physical properties of biodiesel fuel", Applied Thermal Engineering, Vol. 31, pp. 235-242, 2011.
[2] Ayhan Demirbas and Fatih Demirbas. "Importance of algae oil as a source of biodiesel", Energy Conversion and Management, Vol. 52, pp. 163-170, 2011.
[3] Azam, M.M., Waris, A.A. and Nahar, N.M. "Prospects and Potentials of fatty acid methyl ester of some non-traditional seed oil for use as biodiesel in India", Biomass and Bioenergy, Vol. 29, pp. 293-302, 2005.
[4] CS Aalam CG Saravanan, M Kannan. Experimental investigations on a CRDI system assisted diesel engine fuelled with aluminium oxide nanoparticles blended biodiesel. Alexandria Engineering Journal, Vol. 54 (3), 2015, Pages 351-358.
[5] Chisti, Y. "Biodiesel from microalgae", Biotechnology advances, Vol. 25, pp. 294-306, 2007.
[6] Ganapathy, T., Gakkhar, R.P. and Murugesan, K. "Influence of injection timing on performance, combustion and emission characteristics of Jatropha biodiesel engine", Applied Energy, DOI 10.1016/j.apenergy. 2011.05.016, 2011.
[7] Donghui Qi, Michael Leick, Yu Liu and Chia Fon F. Lee. "Effect of EGR and Injection timing on combustion and emission characteristics of split injection strategy DI-diesel engine fueled with biodiesel", Fuel, Vol. 90, pp. 1884-1891, 2011.
[8] Hariram, V. and Mohan Kumar, G. "The Effect of Injection timing and Combustion performance and Emission parameter with AOME Blends as a Fuel for Compression Ignition Engine", European Journal of scientific research, Vol. 79, pp.653-665, 2012.
[9] Glacio S. Araulo, Leonardo J.B.L. Matos, Luciana R.B. Goncalves and Fabiano A.N. Fernandes, "Bioprospecting for oil production Microalgal strain : Evaluation of oil and biomass production for ten Microalgal strains", Bioresource Technology, Vol. 102, pp. 5248-5250, 2011.
[10] Grima, M.E., Medina, A.R., Gimenez, A.G., Perez, J.A.S., Camacho, F.G. and Sanchez, J.L.G. "Comparison between extraction of lipids of fatty acids from Microalgal biomass", Journal of American Oil and Chemical Society, Vol. 71(9), pp. 955-959, 1994.
[11] Guan Hua, Feng Chen, Dong Wei, Xuewu Zhang and Guchen. "Biodiesel production by microbial biotechnology", Applied Energy, Vol. 87, pp. 38-46, 2010.