Study the Performance of Algae Oil in Diesel Engine with Various Injection Pressure

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Abstract - ***In the recent years, vehicle population increased enormously which increases the demand of fossil fuel. The availability of crude oil supply decreases continuously, these reasons makes the researchers to find new renewable alternative fuel especially biofuels. Some of the vegetable plants like neem, karanja, rapeseed, jatropha, soabean, etc. were already found as successful production of biodiesel. But the problems in these sources were the land availability. Still, it has been reported that the use of biodiesel considerably reduced emission and increase the performance of the engine. The most promising method for the production of biodiesel is transesterification process. Now-a-days researchers have reported the possibility for the production of biodiesel from algae oil because of its high lipid content in nature. In the present study, algae methyl ester is used as the biodiesel in the direct injection (DI) diesel engine. The general optimum biodiesel blend AME20 (diesel 80% and algae methyl ester 20%) was taken for the experiment. The injection pressure of the engine has been varied from 210 bar to 230 bar in the steps of 10 bar. The result of experimental investigation reported that the change in injection pressure with AME20 shows the better performance in the diesel engine as well as reduced the emission characteristics.***

KeyWords: *Biodiesel, Algae oil, Diesel, Transesterification, Injection pressure*

1. INTRODUCTION

The demand of fossil fuel increases rapidly because of the increase in the vehicle population. Decrease in the availability of crude oil supplies and greater environmental stringent norms on pollution had created enormous interest in researchers in formulating and testing biofuels in recent times. The most promising method for deriving biodiesel from renewable energy source is transesterification process. Many vegetables plants were found successful in the production of biodiesel like Neem, Jatropha, Karanja, Cotton seed, Rapeseed, Soyabean, etc. It has also been reported in the literature that the use of biodiesel considerably reduced emission and increased the performance of engine [1, 2]. 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. Many researchers have reported on the possibility for production of biodiesel from algae. The growth of algal by nature itself it has the photosynthesis by using sunlight along with nutrients. Algae have a capability of fixing atmospheric carbon di-oxide and can be grown in intensive culture on a non-arable land. Algae can be converted into biodiesel, Bioethanol, bio hydrogen, bio oil and bio methane through bio-chemical and thermo chemical methods [3]. The growth and oil content in blue green algae has been analyzed the growth factor of algae with a significant change in quantity of nutrients and noticed that under nitrogen deficit condition, the oil content (lipid) was increased in algae with respect to time [4].

In India, algal biodiesel research is being pursued by few research institutes develop technologies for alternative renewable energy using algae. The higher viscosity of the algae oil is major disadvantage of using it as biodiesel, hence it is necessary to reduce the viscosity and to improve the engine performance while using it as biodiesel. There are several methods available to reduce the viscosity of vegetable oil like heating, pyrolysis, transesterification, thermal reduction and many more in which transesterification is the most suited and widely accepted method which involves chemical such as methanol, catalyst like sodium hydroxide and potassium hydroxide in the presence of heat energy. Agarwal *et al.* (2009) has studied the effect of karanja biodiesel on performance and emission characteristics in a single cylinder diesel engine in which he obtained better spray and atomization characteristics when biodiesel was preheated [5]. Ganapathy et al has also investigated the performance, combustion and emission parameters of a compression ignition engine using Jatropha biodiesel at variable injection timing [6]. He advanced and retarded the injection timing by five degree from the rated value with constant injection pressure (200 bars) and found that on advanced injection timing, the performance, combustion and emission was better than the rated timing with a marginal increase in oxides of nitrogen.

Microalgae are unicellular photosynthetic organisms that use light energy and carbon dioxide (CO_2), with relatively higher photosynthetic efficiency. *Chlorella vulgaris* is one of the most attractive algae species for producing biofuels owing to its fast growth and easy cultivation. However, it is yet to be commercially viable due to its high lipid content. Therefore, increasing the lipid content in this species is an important research area that needs to be addressed. The dual requirements of maximizing biomass and lipid production are difficult to achieve. Widjaja [7] reported that various research claims that lipid storage in many microalgae was enhanced under environmental stress. Increasing the lipid content under stress conditions could affect the biomass productivity. The productivity of biomass and the productivity of lipid content of *C. vulgaris* can both be enhanced if specific culture conditions are applied [8]. The lipid content in *C. vulgaris* can be increased by up to 56.6% of the dry biomass weight, by adding 1.2×10^{-5} mol·L^{-1} $FeCl_3$. The lipid content of *C. vulgaris* is significantly affected by the variation in the growing conditions. For example, Converti *et al.* [9] stated that the lipid content of microalgae decreased from 14.71% to 5.90% when the growing temperature increased from 25 to 30 °C.

One method of harnessing microalgae is by producing biodiesel from its oil. Biodiesel fuel gives a comparable engine performance and emission to petroleum diesel. Biodiesel from microalgae oil has received significant attention recently as it is renewable, environmentally friendly and represents the ability to convert CO_2 to oil. Microalgae oil contains high values of palmitic acid, and the concentration of linoleic acid met the requirements of the European legislation for biodiesel. Microalgae biofuels are non-toxic, highly bio-degradable, contain no sulphur and the leftover materials (after extracting the oil) can be used for ethanol production or as soil fertilizer. Microalgae have high biomass and high lipid productivities per unit of area in comparison with other crops. Chisti [1] reported that the demand for fuel in the transportation industry can only be covered by microalgae as a renewable source. It was reported that microalgae can produce the same amount of biodiesel (for 30% w/w oil content) compared to rapeseed or soybean crops using around 49- to 132-times less land. Furthermore, microalgae are non-edible and can grow under various conditions in which there is no significant impact on the human food supply chain.

The properties of biodiesel depend on its fatty acids (FA) composition. The biodiesel fuel properties are the outcome of its individual fatty ester's properties and structure such as chain length, degree of unsaturation and branching of the chain. Those parameters of the fatty acid esters influence cetane number, heat of combustion, cold flow viscosity and exhaust emissions. Ramírez-Verduzco, *et al.* [10] estimated density, viscosity, cetane number, and the higher heating value for tallow and soybean biodiesel using a developed empirical equation. They found that the increase in the number of double bonds in the fatty acid methyl esters (FAMEs) causes a reduction in the values of cetane numbers, viscosity and the higher heating values.

The other way of utilizing microalgae or its constituents is by producing emulsion fuels. Emulsion fuels is a term usually used to describe mixtures of diesel and/or biodiesel with water. Owing to the differences in the physical and chemical properties of the mixture components (*i.e.*, water, diesel or biodiesel), emulsifiers are normally used to facilitate the interaction between the mixture components and prolong the stability of the emulsion.

2. MATERIALS AND METHODS

2.1 Preparation Of Biodiesel

The Chlorella vulgaris alga was selected as the source of material for biodiesel, which is having high lipid content of upto 55%. It was cultivated in the open pond method near the seashore area at Portonovo, Tamilnadu, India. 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 isoproponal 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 65^{0}C in the roto evaporator, the solvent and lipid was separated. Transesterification method was chosen to extract the biodiesel from the algae oil. In this method, 18 ml of methanol, 1.5 gm of potassium hydroxide was added with one litre of algae oil in the reactor. The reaction was conducted for one hour at 60^{o}C 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 – 1. Properties of Diesel and Biodiesel

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

2.2 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 figure 1.

Table -2. Specification of the Engine

Make	Kirloskar TV- 1
Type	Single cylinder, vertical, water cooled, 4-Stroke diesel engine
Bore × Stroke	87.5 mm × 110 mm
Compression ratio	17.5:1
Fuel	Diesel
Rated brake power	5.2 kW (7HP)
Speed	1500 rpm
Ignition system	Compression Ignition
Ignition timing	23° bTDC (rated)
Injection Pressure	220 bar
Loading Device	Eddy current dynamometer

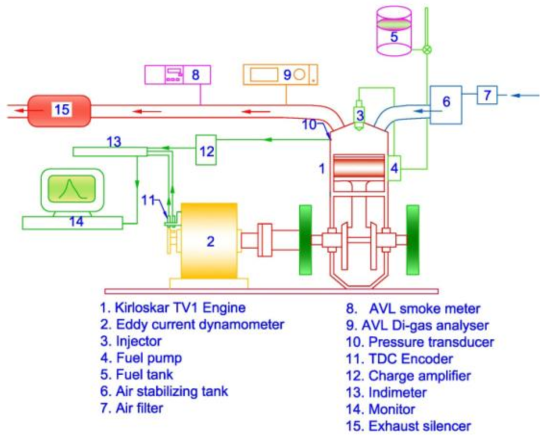

Figure -1. Schematic view of Experimental Setup

2.3 Experimental Test Procedure

The engine was started with the neat diesel fuel with constant speed of 1500 rpm and allowed to run for 20 minutes to obtain the steady state condition. The variable load tests were conducted. At each load, air flow rate, fuel flow rate, exhaust gas temperature, oxides of nitrogen, unburned hydrocarbon, carbon monoxide and smoke density were measured. Then the same procedure was repeated with AME20.

3. Results and Discussion

The experiment is conducted in the single cylinder four stroke water diesel engine. The experiment is conducted with neat diesel fuel and with algae oil 20% (B20) with various injection pressure such as 210 bar, 220 bar and 230 bar. The characteristics curves of the results are plotted in the following figures.

3.1 Brake Thermal Efficiency :

The characteristics curve of the brake power against brake thermal efficiency is shown in the figure 8.1. From the graph, it is observed that almost all the parameter are lies with the same trend where as there is slight increase in the brake thermal efficiency for B20 with 210 bar injection pressure upto part load. The 20 % of algae fuel along with the detarded injection pressure increases the brake thermal efficiency.

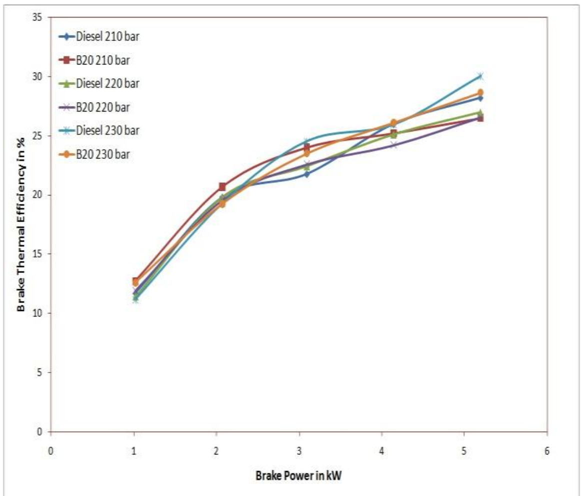

Figure -2. Brake Power against Brake Thermal Efficiency

3.2 Smoke Density

The brake power against smoke density is shown in figure 3. From the graph it is observed that the diesel fuel with standard pressure shows the lesser smoke density compare to all other parameters. All other parameters almost lies on the same trend.

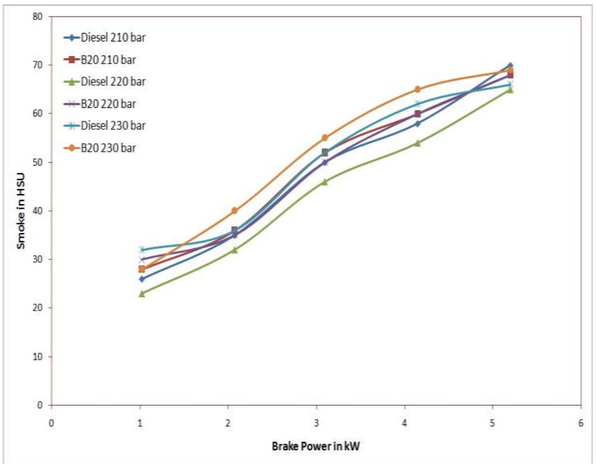

Figure -3. Brake Power against Smoke Density

3.3 Carbon Monoxide :

The brake power against carbon monoxide is shown in the figure 4. From the graph, It is evident that when the load increases the carbon monoxide emission also increases. Compare to the injection pressure, the retarded injection pressure shown less carbon monoxide emission than to the detarded and standard injection pressure for the both cases that is neat diesel fuel and algae fuel.

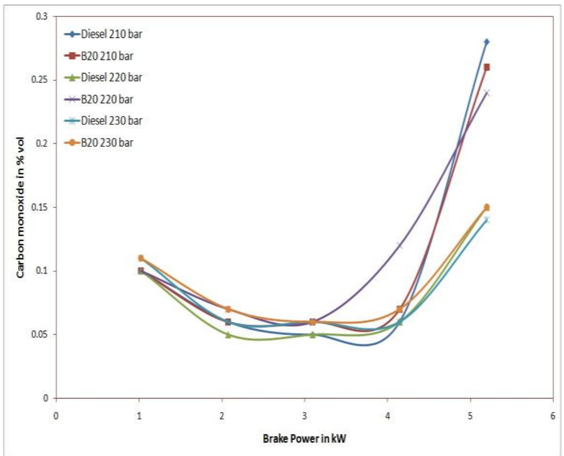

Figure -4. Brake Power against Carbon Monoxide

3.4 Hydrocarbon :

Figure 5 shows the variation of the hydrocarbon emission with brake power for the diesel fuel and algae fuel with various injection pressure. It is observed from the graph that compare to standard injection pressure of neat diesel fuel, all other parameters shows reduced hydrocarbon emission. Especially B20 with standard injection pressure shows the maximum reduction in the hydrocarbon emission.

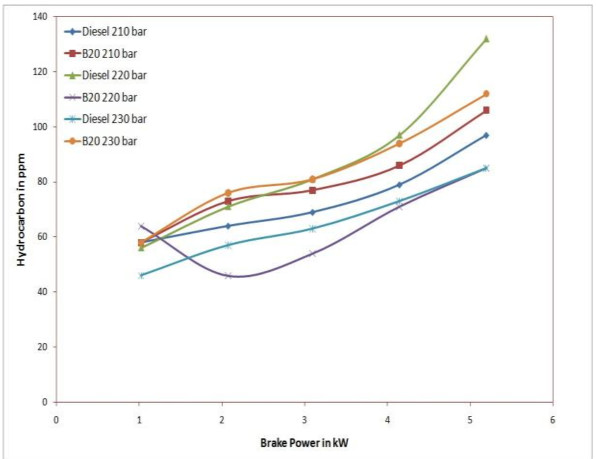

Figure -5. Brake Power against Hydrocarbon Emission

3.5 OXIDES OF NITROGEN :

The oxides of nitrogen results are presented in the figure 6. It is observed that the oxides of nitrogen emission for the detarded injection pressure that is for 210 bar in both cases that is for neat diesel fuel and B20 shows the maximum reduction compare to that of all other parameters.

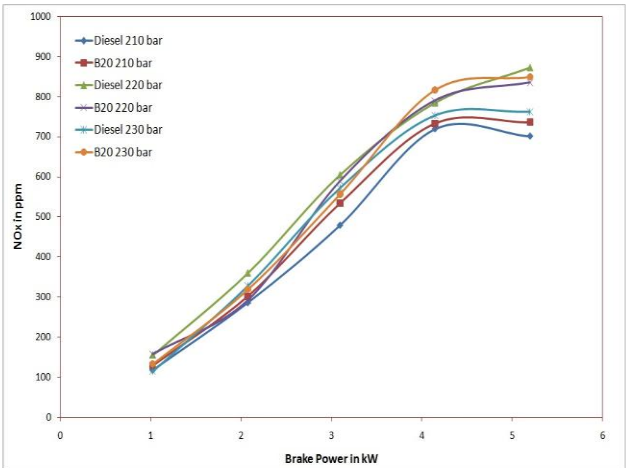

Figure -6. Brake Power against Oxides of Nitrogen

4. Conclusion

The algae fuel is chosen as the potential non-edible oil for the production of biodiesel. Based on the experimental investigations carried out on the single cylinder four stroke diesel engine with neat diesel fuel and B20 algae fuel with various injection pressure such as 210 bar, 220 bar and 230 bar the following conclusion is drawn.

- The brake thermal for B20 210 bar shows the slight increase compare to that of diesel fuel and all other parameters.
- Diesel fuel with standard injection pressure shows lesser smoke density compare to all other parameters.
- The carbon monoxide for neat diesel fuel and B20 shows the maximum reduction compare to all other parameters.
- The standard injection pressure with B20 shows the maximum reduction in the hydrocarbon emission.
- The oxides of nitrogen emission for neat diesel and B20 with injection pressure of 210 bar shown the maximum reduction compare to that of all other parameters.

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 pressure 210 bar shows the considerable change in the performance as well as emission characteristics.

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