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Study of performance of algae oil in diesel engine

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ABSTRACT

Increasing consumption of petroleum fuels all over the world and limitations to the extraction of it has led to measurable increase in its prices per liter. Also, a concern towards its environmental effects is limiting its use. This is asking for an alternate fuel source which will provide a comprehensive solution. Biodiesel is one of the alternatives which are being widely studied. Production of biodiesel from oil seeds is limited by crop land displacement. Production of biodiesel from algae is a promising option. As it is cultivated in ponds, there will be no crop land displacement and its yield is more than that of oil seeds. The present work aims to focus on the performance of a diesel engine with algae oil as fuel. In order to use the oil in engine, its blends with the petroleum diesel were prepared. The properties of algae oil and its blends were tested and the results were compared with properties of neat diesel. It is found that, the properties of neat algae oil and its blends are very close to the properties of neat diesel. Also the calorific value of the blends of algae oil is very close to neat diesel. The results of the tests are inspiring for the aim of this project. This work further proposes to study the performance of algae oil and its blends in diesel engine. The different performance parameters will be studied and the results will be compared with the results of neat diesel.

Keywords— Algae Biodiesel, Biodiesel Blends, Brake Power, Emissions, Specific Fuel Consumption

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I. INTRODUCTION

India is one of the fastest growing markets in the world. The economic growth of country is driving energy consumption across all major sectors. It's making India fourth largest primary energy and petroleum consumer [7]. As the country has limited resources, it makes us think of an indigenous source. Biodiesel, from long is being studied as a promising alternative.

India being an agricultural country, assures enough raw material to produce biodiesel from edible and non-edible oil seeds. However, food security may restrict us to use only non-edible sources for production of biodiesel. Jatropha, rapeseed, soybean, palm, sunflower oils are mostly used for production of biodiesel. Apart from oil seeds, animal fats can also be used for production of biodiesel.

Though the oil seeds are very regular source for production of biodiesel, it's associated with the problem of crop land displacement. The land which will be used for production of these oil seeds is the same which was producing edible sources. Hence the total land availability for production of edible sources might decrease. This, in turn, will reduce the production of edible oil, increasing their prices. Production of biodiesel from microalgae could be a comprehensive solution to this problem. As these could be grown in ponds or bioreactors, crop land displacement can be avoided. Hence it proves to be a very good alternative along with their better yield than oil seeds.

II. OVERVIEW OF ALGAE BIODIESEL

Algae are unicellular or multi cellular organisms that photosynthesize, but lack the features such as leaves, roots, seeds and flowers. They can commonly be found in aquatic—both freshwater and marine—environments. The microalgae can be grown in both open-culture systems such as ponds, lakes and raceways, or in highly controlled closed-culture systems like photo bioreactors, similar to those used in commercial fermentation processes. The photosynthetic growth of micro algal biomass require light, carbon dioxide, water, organic salts and temperature of 20- 30 °C. Cultivating algae in open system is most economical, as it requires least expenses. But the biomass produced in such open system is limited and to increase the yield, closed culture system can be used.

The algal oil is found inside plant cells, linked with proteins and a wide range of carbohydrates like starch, cellulose, hemi-cellulose and pectin. The cell content is surrounded by rather thick wall which has to be opened so the protein and oil can be released. Various methods are available for the extraction of algal oil, such as mechanical extraction with hydraulic or screw, enzymatic extraction, chemical extraction through different organic solvents, Ultrasonic extraction and supercritical extraction using carbon dioxide.

Biodiesel can be produced by transesterificaton of algal oil. The transesterification is the reversible reaction of fat or oil (which is composed of triglyceride) with an alcohol to form fatty acid alkyl ester and glycerol. The reaction occurs stepwise: triglycerides are first converted to diglycerides, then to monoglycerides and finally to glycerol [18].

Microalgae are capable of synthesizing more oil per acre than the terrestrial plants as they can double their biomass within 24 hrs [19]. Hence using microalgae to produce biodiesel will not compromise production of food, fodder and other products derived from crops.

III. EXPERIMENTAL SETUP

In the present work, the performance of different blends of diesel-biodiesel is studied in diesel engine. For this purpose, different blends of petroleum diesel and biodiesel were prepared and named B00, B10, B20 and B30. Here, B00 is neat diesel and is used to compare the performance of biodiesel. B10, B20 and B30 are the blends of diesel and algae biodiesel where algae biodiesel is mixed with diesel in proportion of 10%, 20% and 30% respectively by volume. In order to characterize, the properties of bends were studied and compared with diesel. It is found that, the properties of algae biodiesel-diesel blend are very close to the properties of petroleum diesel.

Table I Properties of diesel-biodiesel blends

Sr. No.	Test parameter	B00	B10	B20	B30
1	Density (gm/cc)	0.834	0.801	0.803	0.807
2	Viscosity (Cst)	2-4.5	2.70	2.90	3.10
3	Calorific value(MJ/Kg)	45.20	42.40	42.00	41.70
4	Cetane Number	46 (min.)	47	49	52
5	Flash point (°C)	55 (min.)	78	86	94

The engine used for the experimentation is Kirloskar single cylinder diesel engine. Being a VCR engine, the compression ratio can be varied between 12 and 18. The hydraulic dynamometer is used to apply the load on engine output shaft. Data acquisition system is used to collect various parameters of engine. A software ‘’Engine soft” is used to analyze the data. “AVL Digas 444” is a five gas analyzer used for analyzing the emissions of engine.

Table II Engine Specifications

Engine Make	Kirloskar TV1 VCR Engine
Number of Cylinders	1
Cycle	4 Stroke
Rated Power	3.5 KW @ 1500 rpm
Cylinder Diameter	87.5 mm
Stroke Length	110 mm
Connecting Rod Length	234 mm
Compression Ratio	12 to 18
Cooling Medium	Water Cooling

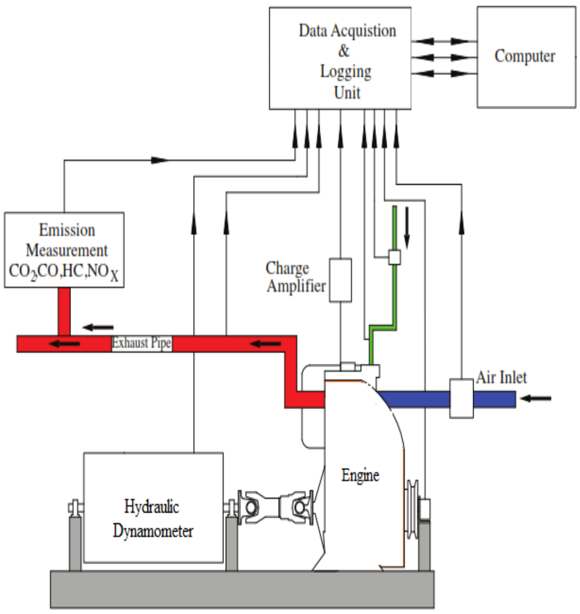

Fig. 1 Engine Test Setup

IV. RESUTS AND DISCUSSION

1) Effect of Biodiesel Properties

a. Density

Density is measure of mass per unit volume of a material. Biodiesels, in general, are characterized by higher densities than conventional petroleum diesel. This means, volumetrically operating fuel pumps will inject greater mass of fuel. This will affect the air fuel ratio of the engine [14].In present study, density of biodiesel blends is found to be increasing with the increase in blend ratio.

b. Viscosity

It is measure of internal resistance to flow of a fluid. Higher viscosity of fuel enhances fuel spray penetration and thus improves air fuel mixing [38]. However fuel with higher viscosities cannot be used safely in compression ignition engines [14]. It is seen that the viscosity of blend increases with increase in blending ratio. This limits the blending ratio of diesel and biodiesel.

c. Calorific Value

Calorific value is the measure of heat content of fluid or fuel. It is very well established that, calorific value of biodiesel is lower than petroleum diesel. The same is observed in the study. This also reduces the calorific value of biodiesel blends. This, in turn, means that more fuel will have to be consumed for getting same work output from an engine which is using petroleum diesel. This will increase the specific heat consumption and may lower the torque and power output of the engine.

d. Cetane Number

Cetane number is one of the most important characteristic of fuel. It is a dimensionless number and indicates the ignitability of the fuel [14]. Higher cetane number of fuel promotes faster auto ignition of fuel and reduces the emissions of nitrogen oxides [14]. Cetane number of biodiesel blends in present study is found to be higher than diesel, which creates a possibility better combustion and knock free working of engine.

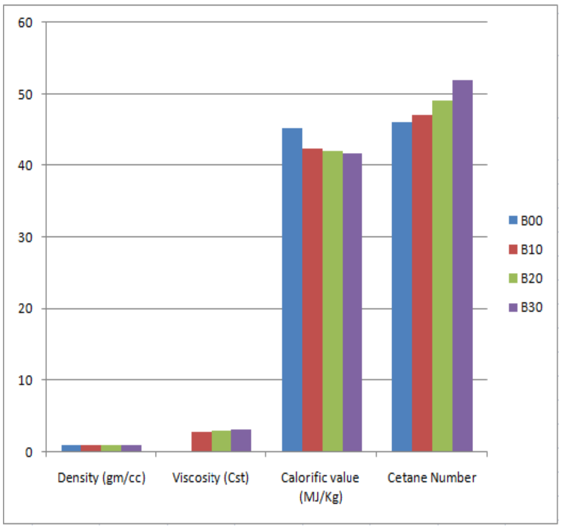

Fig. 2 Comparison of Biodiesel Properties

2) Torque

The Engine was tested for different compression ratio and different loads. Result shows minimal variation in torque for different biodiesel blend as compared to diesel. At lower loads, torque produced by biodiesel blends is closely similar to the torque produced by diesel. Whereas at higher loads, biodiesel blends show improvement in torque. Fig. 3 shows the torque variation for diesel and biodiesel blends.

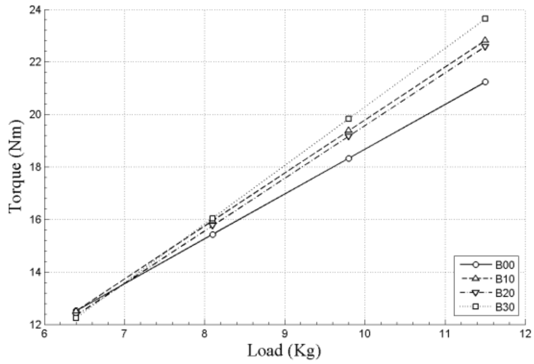

Fig. 3 Torque Vs Load

3) Brake Power

It can be seen that, there is minor effect of blending on brake power as compared to diesel. The variation lies within 6%.This may be because of lower calorific value of biodiesel. Brake power slightly decreases for biodiesel blends at lower loads, but shows improvement at higher loads. Biodiesel blends show better performance than diesel at higher loads. Fig. 4 shows variation in brake power with increasing load. It can be observed, at higher load and higher compression ratio, biodiesel blends show better performance.

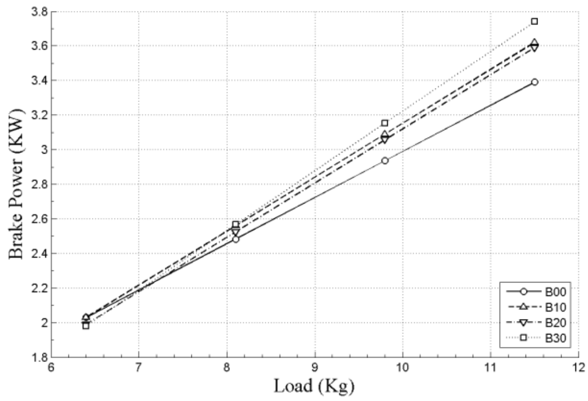

Fig. 4 Brake Power Vs Load

4) Brake Thermal Efficiency

Brake Thermal Efficiency is a function of heating value. With the increase in blend proportion, Brake Thermal Efficiency decreases for lower loads and lower compression ratio. This decrement is minimal and lies within 6.18% as compared to neat diesel. This could be because of lower heating value of biodiesel. Slight improvement is observed with increase in load. It can be observed from Fig. 5 that, B10 blend shows better result for all loads at higher compression ratio. At lower load and compression ratio, it shows a minor decrement of 3.52%. At higher load and compression ratio, all biodiesel blends show better performance.

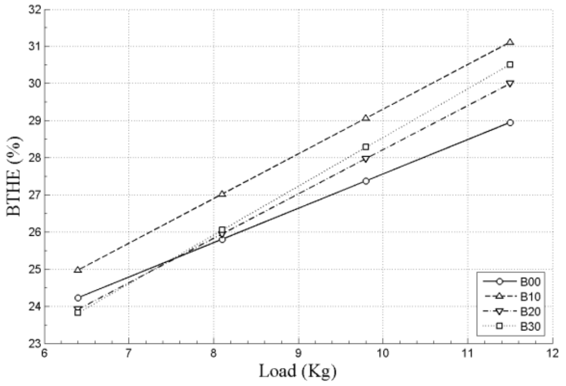

Fig. 5 Brake Thermal Efficiency Vs Load

5) Cylinder Pressure

A minor decrement is observed in cylinder pressure for blends of biodiesel as compared to diesel. Fig. 6 shows the variation in cylinder pressure with crank angle for diesel and biodiesel blends. It can be seen that B10, B20 and B30 blend shows a decrement of 3.55%, 6.65% and 4.41% respectively as compared to diesel. This could be because of slower heat release rate of biodiesel.

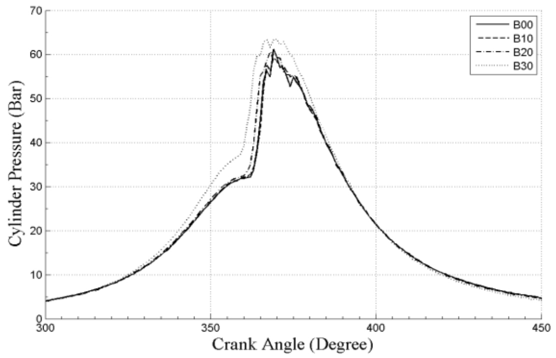

Fig. 6 Cylinder Pressure Vs Crank Angle

6) Specific Fuel Consumption

Fig. 7 shows the variation in specific fuel consumption for diesel and biodiesel blends. Specific fuel consumption is slightly higher at lower loads, but shows moderate improvement at higher loads. It increases with increase in blending ratio. This could be because of lower calorific value of biodiesel. It is seen the B10 blend shows better fuel efficiency than other blends, except that it shows the increase of 2.78% at 60% load and compression ratio of 15. All blend shoe better fuel efficiency at higher compression ratio and higher loads.

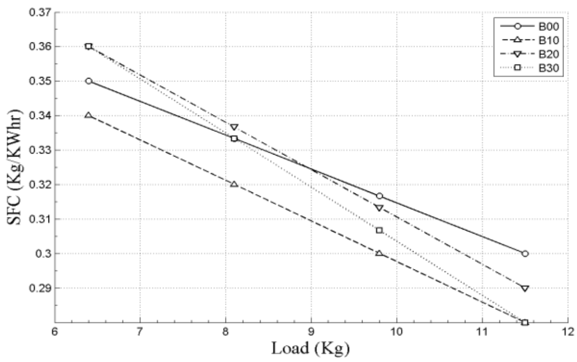

Fig. 7 Specific Fuel Consumption Vs Load

7) Exhaust Emissions

Study shows a minor decrement in emissions of CO and HC for lower loads. At higher loads emissions of HC are almost similar to that of diesel. B20 blend shows better results for emissions of CO and HC. Emissions of nitrogen oxides are increases with increase in blend ratio. This may be due to improved automation of biodiesel blends and higher peak temperatures.

V. CONCLUSION

In the present work, the suitability of blends of algae biodiesel with diesel is studied for a diesel engine. It is seen that,

- The cylinder pressure varies up to 6.65% for blends of biodiesel as compared to diesel.
- The torque and brake power have minimal effect of blending.
- Thermal efficiency of the engine decreases partially at lower loads and is improved at higher load and compression ratio.
- The specific fuel consumption increases slightly with increase in blending ratio.
- Emissions of CO, CO2 and HC have minor effect but emissions of nitrogen oxides increased with increase in blending ratio.

It can be concluded that, algae biodiesel can be blended with diesel for use in present engines without any modification.

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