Impact of Bio-Oil on Combustion, Performance and Emissions of Diesel Engine

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ABSTRACT

In view of the fast depletion of fossil fuel, the search for alternative energy has become inevitable. Fossil fuels are the important source of air pollution and greenhouse gases, and it is considered to be the prime cause behind the global climate. Bio-fuels from algae are mostly preferred as a renewable and ecofriendly.

The bio-oil extracted from spirulina algae through pyrolysis method at an optimum temperature of 350ºC, and the bio-oil properties were analysed. The performances of diesel engine for various loading conditions were carried out for B10 and B30 and it showed that maximum output power at 100% load condition is nearly same for S10D90, S30D70 and diesel fuel. The Specific fuel consumption is nearly same when compared with diesel. The Brake thermal efficiency of S30D70 decreases by 5%, and the combustion characteristic of peak heat release rate is lesser and also there is a reduction in HC, CO, CO_2 emission at full load, with slight increase in NO_X emission. The experimental result shows that the use of bio-oil in diesel engine is a suitable alternative to diesel.

KEY WORDS: Spirulina (S), Pyrolysis, Diesel Engine, Diesel Fuel (DF), Combustion, Emission.

1. INTRODUCTION

The availability of energy resource plays a major role in the development of a nation. The increase in the consumption of fossil fuels is resulting into climate change which is considered as the most important environmental problem of the present century. The scope of this work is to reveal microalgae as an alternative energy source for producing biodiesel. In a broad-spectrum shows that microalgae is a sustainable energy source for biodiesel. This present paper evaluates the combustion, performance, and emission characteristics of bio fuel and its blends with diesel. The brake power, torque, specific fuel consumption, thermal efficiency and exhaust emissions are reviewed.

Algae: Algae are small plant organisms that are photosynthetic and aquatic with simple reproductive structures, but do not have roots, stems, leaves, or vascular tissue. Photosynthesis is the process of making solar energy available in useable forms for all organic life in the environment. The organisms utilize solar energy from the sun to combine water with carbon dioxide to create biomass. Algae are distributed worldwide in the sea, freshwater, and wastewater. Most algae are microscopic while some are quite large, exceeding fifty meters in length.

Classification of Algae: There are two types of algae; i. Microalgae, ii. Macroalgae.

Microalgae: The single cellular algae are known as microalgae. Microalgae range from small microns to hundreds of microns and exist individually, in chains, in marine or freshwater systems. Microalgae contribute around 40 to 50 percent of the oxygen in the atmosphere and simultaneously consume carbon-dioxide to grow photo auto trophically without additional carbon sources. It has been estimated that around 2,00,000 - 8,00,000 species available but with only 35,000 species described in literature. The extraction of biofuel from microalgae has considerable attention due to the fact that they can be converted into several different types of renewable biofuels such as biodiesel, methane biogas, ethanol, and butanol.

Macro algae: The multicellular forms of algae are known as macroalgae. Macroalgae are large multicellular algae which often grow in ponds. The largest macroalgae, called seaweed, is a kelp plant that can grow up to 100 feet long.

Figure.1. Macroalgae (left) and Microalgae (right)

2. EXPERIMENTAL

Extraction of Algae oil: The extraction of Bio-oil from algae biomass is a costly process which can determine the sustainability of algae-based biodiesel. Extraction can be broadly classified into three methods: a) Mechanical method, b) Chemical method, c) Thermal method.

Drawbacks of the methods: a) The Mechanical extraction process requires drying the algae, which is energy intensive, b) The use of chemical solvents require safety and health issues, c) Supercritical extraction requires high pressure equipment that is both expensive and energy intensive.

Extraction of oil from Algae through Pyrolysis method: Pyrolysis is a thermal degradation of biomass at elevated temperatures in the absence of oxygen. It this process there is the simultaneous change of chemical composition and physical phase, and is irreversible.

Figure.2. Experimental setup of Pyrolysis

Pyrolysis involves the degradation of biomass (or other organic material) into bio-oil, syngas and charcoal. The extraction of bio-oil from spirulina without a catalyst for elevated temperature was investigated, it was concluded that pyrolysis at 350°C for 175 min is suitable for complete decomposition of the algae. At these conditions a dry bio-oil yield of 45 % was achieved; this oil contained 42 % of the energy originally present in the algae. The major drawback with pyrolysis is that the biomass must be dried. The excess of 50 % of the energy in the algae is lost in the vaporization of water. A further issue with pyrolysis is that the resulting bio-oil requires further upgrading to be utilized as a transport fuel replacement.

Table.1. Oil Extraction

S.no	Temp. in ^{0}C	Weight of biomass In kg	Time to reach max temp In hrs	Oil extracted In ml
1	300	1	1.45	0.403
2	350	1	2.00	0.439
3	400	1	2.30	0.427

Table.2. Properties of Spirulina oil

Temp	Density(ρ) kg/m^3	Flash point °C	Fire point °C	Kinematic Viscosity in Centistoke	Calorific value (kJ/kg)
300°C	986	130	160	0.2726	30900
350°C	1019	125	150	0.81931	31200
400°C	1050	119	146	0.83931	31600

Blending of Bio-oil with Diesel: Blending is defined as the process of adding bio-oil with the conventional diesel. The world uses a system known as the "B" factor to mix the bio fuel with diesel. There are two basic methods for blending biodiesel with petroleum diesel: Splash method, In line method.

Method of Blending: The Spirulina algae oil taken from 350°C is blended with diesel directly in various proportions. The proportions ratios are given as 1:9, 2:8, 3:7, 4:6, and 5:5. The type of blending used is Splash mixing, S30 and S10, where S30 represents 30%of Spirulina algae oil and 70% of diesel. LikewiseS10 represents 10% of Spirulina algae oil and 90%of diesel.

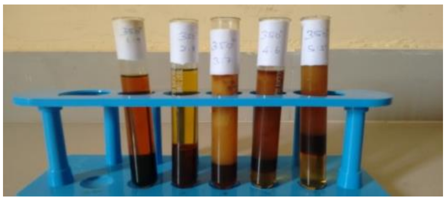

Figure.3. Blending of Spirulina algae

In 10ml test tube various ratio has been blended. From this various ratios, it is found that the ratio 3:7 and 1:9 blended nicely.

Table.3. Properties of blended oil

Oil	Density(ρ) in kg/m^3	Flash point in °C	Fire point in °C	Kinematic Viscosity in Centistokes	Calorific value (kJ/kg)
Diesel	860	51	56	3.56	43500
S10D90	875	60	63	4.7	42037
S30D70	907	66	70	7.19	39113

Engine Test Procedure: The Engine test carried out in a single cylinder four-stroke air-cooled diesel engine at rate of 4.4 kW and 1500 rpm. The Engine specifications are given in Table5.1. The engine was coupled to a dynamometer with control system. The fuel consumption was measured with the help of digital stopwatch, and the exhaust gas temperature was measured by thermocouple in conjunction with a digital temperature indicator. An orifice meter attached with tank measures air consumption of an engine with the help of a U tube manometer.

Figure.4. Diesel Engine Setup

Exhaust emission from the engine was measured with the gas analyzer. Smoke intensity was measured with the help of a Smoke meter.

Table.4. Engine Specification

Name	Kirloskar Oil Engine TAF 1
Type	Four Stroke, Single Cylinder Vertical Air Cooled Diesel Engine
Rated Power	4.4 KW
Rated Speed	1500 rpm
Bore Diameter	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Orifice Diameter	13.6 mm
Coefficient of Discharge (C_d)	0.6

3. RESULT AND DISCUSSION

Performance characteristics:

Brake Thermal Efficiency: Performance test was conducted on the diesel engine for various blends of bio-fuel (S10D90, S30D70) and diesel. The Brake thermal efficiency of Spirulina algae bio-fuel blends and diesel are recorded. The diesel Shows slightly higher Brake thermal efficiency than the blends on all loads because of higher heating values. The S30D70 shows 5% reduction in the efficiency at full load, because the bio-fuel has slightly superior viscosity and lower heating value.

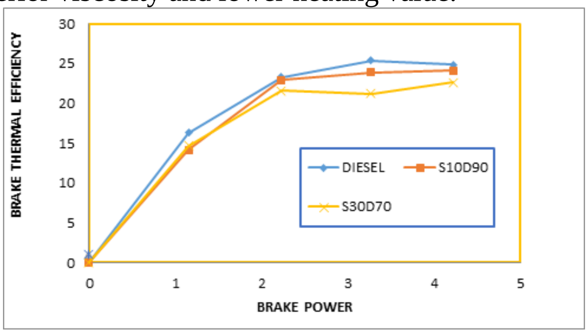

Figure.5. Brake power Vs Brake Thermal Efficiency

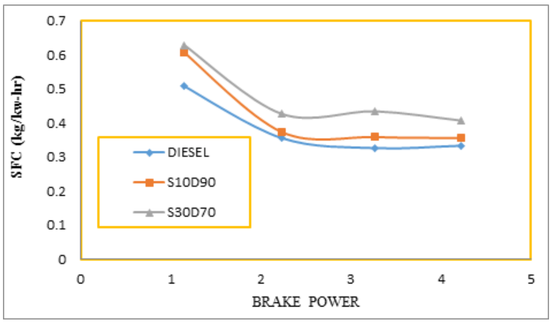

Figure.6. Brake power Vs Specific fuel consumption

Specific fuel consumption: The graph shows that the specific fuel consumption decreases while increasing the brake power of the engine for the blends. Among the blends the minimum SFC for S30D70 fuel is 0.334 kg/kWh against 0.316 kg/kWh of diesel at maximum load.

Emission Characteristics:

Hydrocarbon emission: Hydrocarbon emission depend on combustion efficiency of the engine, it is clearly shown that the HC increases for all the blends when load increases, The hydrocarbon emission reduces for all the ratio of blending compare to diesel. The S30D70 shows the maximum reduction in the HC emission.

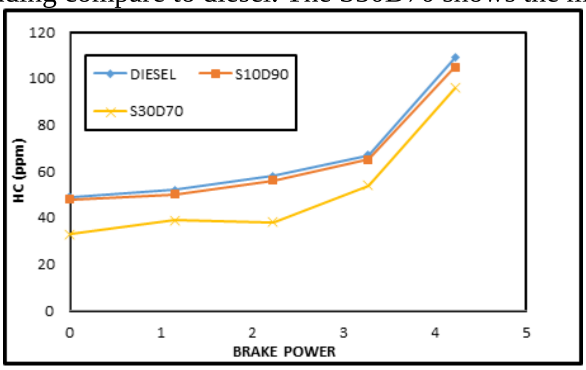

Figure.7. Brake power Vs Hydrocarbon

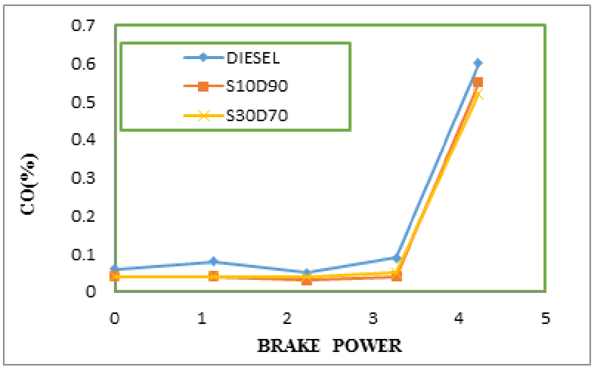

Figure.8. Brake power Vs CO

Carbon Monoxide: The carbon monoxide emission with respect to load is shown in figure 6.4. The carbon monoxide gradually increases with increase in load. The availability of oxygen content in the biolfuel makes the better combustion and it leads to reduction in carbon monoxide emission for the entire blend than diesel. At full load, the carbon monoxide emission of diesel is higher than the biofuel blend in Standard engine. Biofuel has high cetane number which reduces the formation of rich fuel zone which diminishes CO formation. This may also be attributed to lower carbon to hydrogen ratio in bio-fuel.

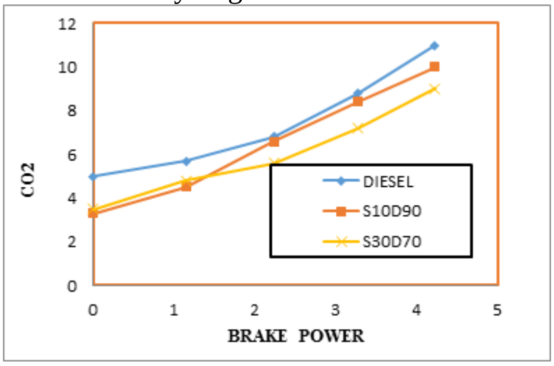

Figure.9. Brake power Vs CO_2

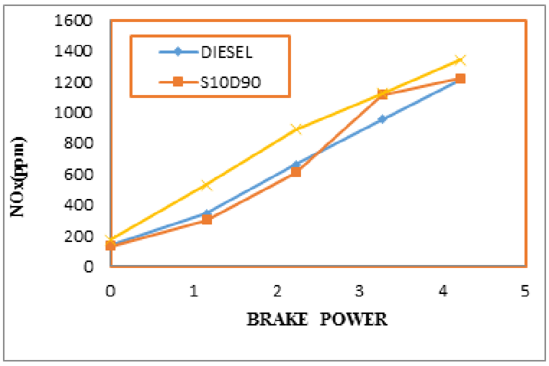

Figure.10. Brake power Vs NO_X

Oxides of Nitrogen Emission: It is clear that the NOx emission increases up to a part load and then decreases. It is revealed that heat release rate decreases and hence the NOx emission is also decreasing. NOx is temperature sensitive. The intense heat in combustion, inherent availability of nitrogen and oxygen from fuel and intake charge create favorable conditions in accelerating the reaction to result into oxides of nitrogen. This is the reason for increased NOx concentrations in diesel engine. In bio-fuel, the oxygen content increases injection advance thereby increasing chances for NOx formation.

Combustion analysis:

Cylinder Pressure Vs Crank Angle Diagram: The cylinder peak pressure at different values of brake power is shown in graph, The peak pressures for Diesel, S30D70 and S10D90 at maximum load operation are 61.87, 63.44, 62.78 bar. The cylinder peak pressure also increases with the increase in the ratio of bio-oil.

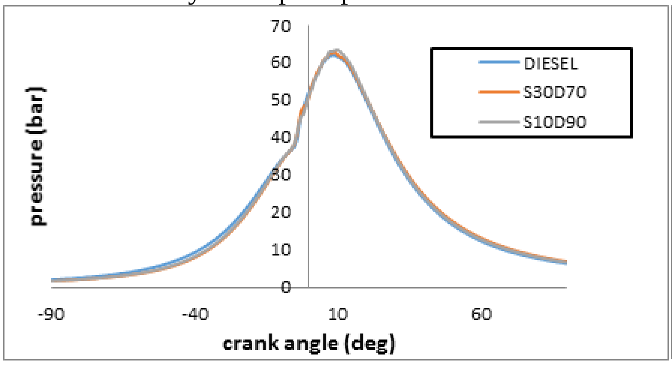

Figure.11. Cylinder Pressure Vs Crank Angle Diagram

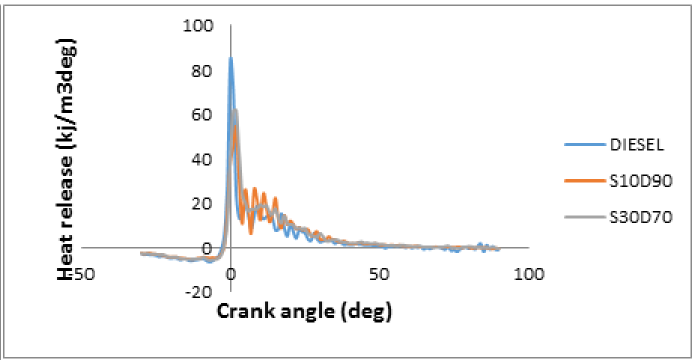

Figure.12. Heat Release rate Vs Crank Angle Diagram

Heat release rate with Crank Angle: The variation of heat release with crank angle is shown in the graph. The main reason for the decreases in the heat release rate is because of less heating value of S10D90 and S30D70 blends as compared to diesel fuel.

4. CONCLUSION

The yield of pyrolysis oil from spirulina is 439 ml at a maximum temperature of 350^{0}C. The viscosity and density of spirulina algae oil are close to the conventional diesel fuel. The Brake thermal efficiency of biofuel increases for all loads but it is slightly less than that of diesel fuel (DF).The Specific fuel consumption gradually reduces with increasing load. S30D70 and S10D90 show closer SFC values with DF. HC emission is very low for no load and peak load for all blends. The smoke opacity of S30D70 and S10D90 are lower than the opacity of DF. The NOx is higher by about 11.8% for S10D90 and 13.03% for S30D70 at maximum load operations than DF, CO and CO_2 emissions are lower than DF. The further improvement in production of bio-oil should be performed in the period of time to promote the alternative fuel.

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