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PERFORMANCE AND EMISSION CHARACTERISTICS OF ALGAE BIO-FUELLED DIESEL ENGINE

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ABSTRACT

During recent years the increasing consumption of fossil fuel has led to the search for alternative energy. Microalgae emerged as one of the potential sources of Bio-fuels from algae, and it is mostly preferred because it is sustainable and environment-friendly. The oil extracted from spirulina and chlorella microalgae through pyrolysis process at a temperature of 350^{o}C, and the bio-oil properties were analysed. When compared to spirulina bio-oil, the viscosity and density of chlorella bio-oil were very close to the conventional diesel fuel. The Experiment was conducted in a single cylinder four stroke diesel engine for various loading conditions and was carried out for B10 blend for spirulina and chlorella algae bio-fuel, CL10D90 showed maximum output power at 100% load condition has been nearly same for diesel fuel than SP10D90, and the Specific fuel consumption is nearly same when compared with diesel. The Brake thermal efficiency of CL10D90 increases by 4% than SP10 D90 and 2% than diesel, and the combustion characteristic of peak heat release rate is higher and also there is a reduction in HC, CO emission at full load, with slight increase in NO_X emission. The experimental result shows that the use of CL10D90 bio-oil in diesel engine is a suitable alternative to diesel.

Key words: Spirulina (SP), Chlorella (CL), Pyrolysis, Diesel engine, Diesel fuel (DF), Combustion, Emission.

INTRODUCTION

The algae fuel is a third generation bio-fuels. The algae fuel is the bio-fuel of the future that will significantly decrease the need of fossil fuels, and it will help to reduce the total amount of harmful gases responsible for environmental problems. While there is no

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doubt that biomass production from algae certainly has the potential to deliver clean energy to the world. The objective of this study is to produce microalgae as an alternative renewable energy source for producing biodiesel. This paper covers the combustion, performance, and emission characteristics of algae bio-fuel and its blends with diesel. Experimental investigation done to find the engine performance of diesel engine using bio-fuel and its blends with diesel in terms of brake power, specific fuel consumption (SFC), Brake thermal efficiency (BTE) and exhaust emissions.

Algae

Algae are probably the most efficient organisms known when it comes to converting sunlight and carbon dioxide into biomass. That biomass includes oils and carbohydrates that are used in today's algae industry to create fuels. Algae can be grown on non-arable land, most of them do not require fresh water, and their nutritional value is high. Another major advantage of algae as a fuel feedstock is its massive consumption of carbon dioxide. Many of you probably already know that carbon dioxide is a greenhouse gas mostly responsible for climate change problem that is released in the atmosphere by fossil fuels burning.

Extraction of oil from algae is costly and there are more disadvantages for the conventional methods. Extraction can be broadly categorized into three methods:

(a) Mechanical extraction

(b) Chemical extraction

(c) Thermal extraction

Pyrolysis

Pyrolysis is a thermal degradation process of biomass at optimum temperatures in the absence of oxygen. It involves the simultaneous change of chemical composition and physical phase, and is irreversible. The algae biomass feed in to the reactor chamber and heated in the absence of oxygen. For this nitrogen gas is passed at 0.5 kg/cm^2. In the absence of oxygen, the heat is used to break the chemical bonds by vaporizing many constituents of the biomass. Once vaporized the products can be cooled to form a liquid, this liquid can be used for fuel once the process is complete there are three major products produced: oil, charcoal and gas. Algae pyrolysis has many advantages, such as the ability to recover fuel without modification, and it has low viscosity, consequently the pyrolysis yield higher bio-fuel.

Table 1: Oil extraction

S. No.	Species	Temp. (°C)	Weight of biomass (Kg)	Time to reach max temp. (hrs)	Oil extracted (Kg)
1	Spirulina	350	1	2.20	0.439
2	Chlorella	350	1	1.90	0.480

Blending of bio-oil with diesel

The Spirulina algae and chlorella algae oil taken at 350°C and blended with diesel. The proportionate ratios given as 1:9. The type of blending used here is splash mixtures SP10 and CH10 where SP10D90 represents 10% Spirulina algae oil and 90% of diesel. Likewise CH10D90 represents 10% of chlorella algae oil and 90% of diesel.

Table 2: Properties of blended oil

Oil	Density (ρ) (kg/m^3)	Flash point (°C)	Fire point (°C)	Kinematic viscosity in centistokes	Calorific value (kJ/kg)
Diesel	860	51	56	3.56	43500
SP10D90	875	60	63	4.7	42037
CL10D90	872	58	61	4.2	42859

Engine test procedure

The Experiment was conducted in a single cylinder four-stroke air-cooled diesel engine developing 4.4 kW at 1500 rpm. This engine was coupled to a dynamometer with control system.

Fig. 1: Diesel engine setup

Time taken for fuel consumption was measured with the help of a digital stopwatch. The thermocouple in conjunction with a digital temperature indicator was used for measuring the exhaust gas temperature. An orifice meter attached with surge tank measures air consumption of an engine with the help of a U tube manometer.

Smoke intensity was measured with the help of a Bosch Smoke meter. Bosch Smoke meter usually consists of a piston type sampling pump and a smoke level measuring unit. Two separate sampling probes were used to receive sample exhaust gases from the engine for measuring emission and smoke intensity.

RESULTS AND DISCUSSION

Performance characteristics

Brake thermal efficiency

Performance test were conducted on the diesel engine for various blends of bio-fuel (SP10D90, CL10D90) and diesel. The brake thermal efficiency of Spirulina algae bio-fuel, Chlorella bio-fuel blends and diesel are recorded. The CL10D90 Shows slightly higher brake thermal efficiency than the SP10D90 and diesel on all loads because of low viscosity and higher heating values. The maximum efficiency of CL10D90 fuel at 100% load is 30.4% which is higher compared to diesel. This slight change in brake thermal efficiency is due to decrease in oxygen content in the CL10D90 and SP10D90 blends the brake thermal efficiency decreases marginally with other two all fuels

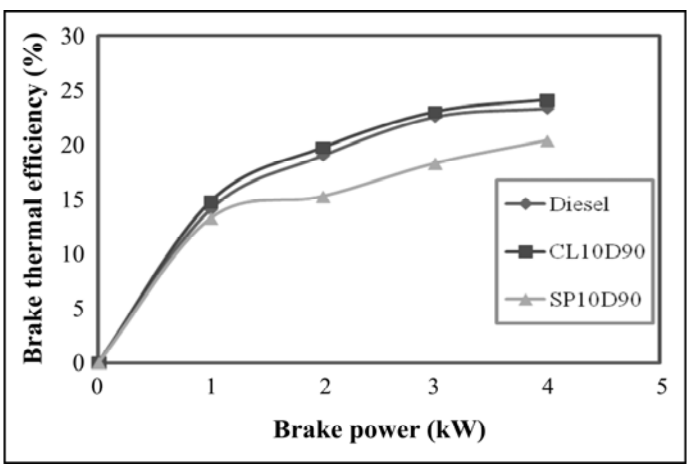

Fig. 2: Brake power VS brake thermal efficiency

Specific fuel consumption

The graph shows that the specific fuel consumption decreases while increasing the brake power of the engine for all the blends. Among the blends the SFC for CL10D90 fuel is nearer to diesel for all the loads. It was inferred as specific fuel consumption of SP10D90 was quite high when compared with neat diesel. It is due to the viscosity and density was also found to be on the higher and lower calorific value of the fuels.

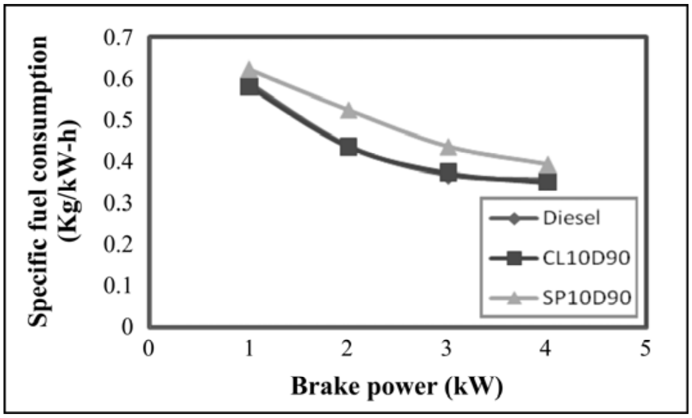

Fig. 3: Brake power VS specific fuel consumption

Emission chracterstics

Hydrocarbon emission depends on combustion efficiency of the Engine the hydrocarbon emission reduces for all the blends compare to diesel. The CL10D90 shows the maximum reduction in the HC Emission than SP10D90.

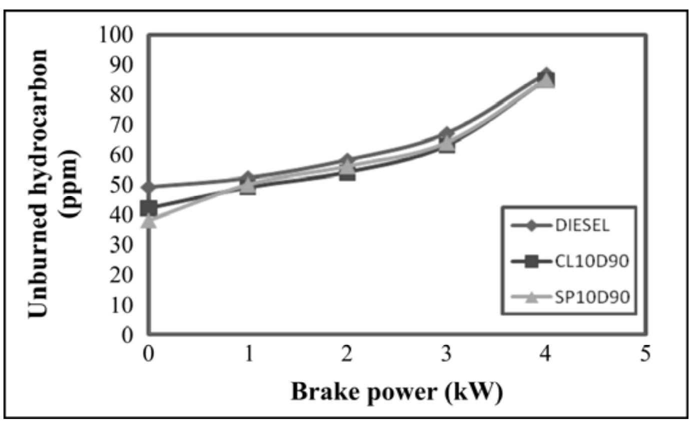

Fig. 4: Brake power VS hydrocarbon

There is more oxygen chemically bounded with oxygen in biofuel, which is an additional source of oxygen other than oxygen present in the intake air.

Carbon monoxide emission shows the incomplete combustion. There is a decrement in emission of carbon monoxide for all the blends. The blend shows the lower emission, the reason is a high viscosity of bio-fuel.

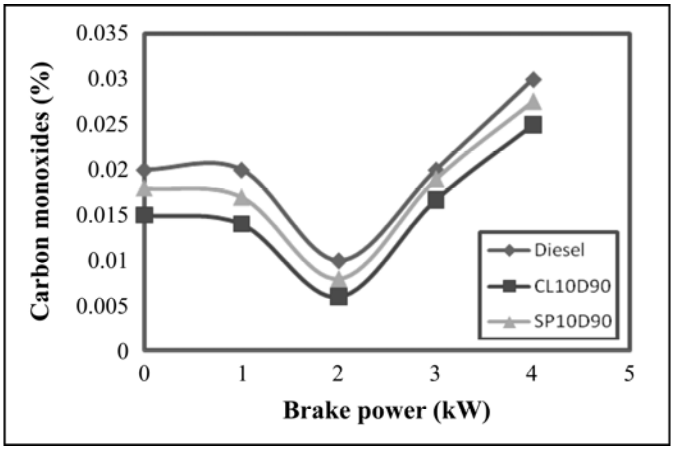

Fig. 5: Brake power VS caron monoxide

The emission of NO_X depends on availability of oxygen in the fuel. It is observed that NO_X emission of CL10D90 increases for all the loading conditions. The higher premixed combustion is due to higher centane number of biofuel, which initiates the combustion early.

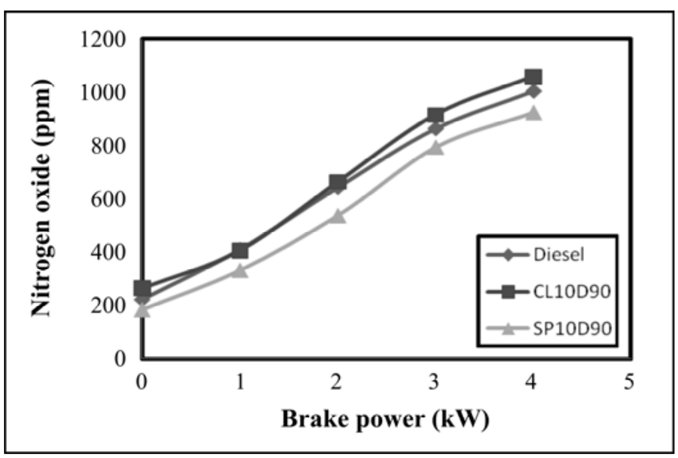

Fig. 6: Brake power VS nitrogen oxide

CONCLUSION

This study concluded the effect of bio-fuel on the combustion characteristics, performance and exhaust emissions of diesel engines using bio-oil from Spirulina and chlorella microalgae. The performance of diesel engine under various loading conditions showed that maximum output power at full load condition for CL10D90 is slightly higher than SP10D90and diesel fuel. The CL10D90 increases the brake thermal efficiency by 4%, at full load condition than SP10D90 and 2% than diesel. The specific fuel consumption of CL10D90 is higher when compared with SP10D90 and diesel. HC, CO and CO_2 emissions decrease with increase in load for CL10D90 and SP10D90 than diesel, whereas NO_X increases at full load condition for CL10D90 than SP10D90 and diesel. The CL10D90 blend is the best suitable alternate energy for the diesel fuel.

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