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Emission Analysis of *Chlorella* sp. Microalgae Biodiesel with Oxide Nano Additives in Diesel Engine

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The *Chlorella* sp. biodiesel was produced from the microalgae oil via transesterification process. Three combinations were studied. Blend of biodiesel (20%) with diesel (80%) was prepared and denoted as B20. Then the TiO_2 nanoparticles were added to each B20 blend samples in a quantity of 50 and 100 ppm using an ultrasonicator. In compliance with the American Society for Testing and Materials (ASTM) fuel requirements, the biodiesel blends have been characterized. In an unaltered four-stroke diesel engine using various loads, the biodiesel blends were studied. The experimental outcomes show a decrease in exhaust emissions in terms of CO, HC, NOx, and Smoke.

Keywords: ASTM, Blending, Transesterification, Ultrasonicator

Introduction

Nowadays, diesel fuel engines power a lot of agricultural equipment, transport vehicles and many small scale industries. Diesel engines have such potential that as much around two-thirds of all farm equipment, 90 % of transport vehicles as well as one-fifth of water pump use them in India. Ninety-six per cent of the larger vehicles which move agricultural products to railheads as well as storage warehouse tend to be powered with a diesel engine. One hundred per cent from the cargo locomotives, maritime river grain barrages and ocean-going ships which provide these kinds of products to markets in the home as well as overseas are generally run on diesel. Diesel being a non-renewable fuel is predicted to be in short supply in future for which biofuels may become saviour. However, the problem which arises is that often most biofuels are not able to run an engine alone. They must be blended with other fuels such as diesel or gasoline to obtain the desired effects in the present engine. These biofuels can be categorised into three generations: the first generation, linked to biofuels generated from food sources, the second generation, linked to biofuels generated from cellulose derivatives, and the third generation, primarily based on microalgae, intended as a 'protein crop' for fuel production.[1] Taking into account the high potential of biodiesel microalgae derived from Chlorella sp. Species with TiO_2 nano additives was defined by compliance with diesel engine fuel requirements.

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Materials and Methods

In-situ Transesterification Reaction

The oil extraction typically recuperates all-oil content coming from biomass. According to Karthikeyan *et al*. 2017, solvent extraction is a suitable method rather than mechanical extraction for oil and fat.[2] However, there is a way called in-situ transesterification which involves direct bio-diesel production from wet algae avoiding the steps of drying, oil-extraction and transesterification. The microalga was contained in a 250 ml reaction vessel containing a mixture of methanol, H_2SO_4, and chloroform (1.7:0.3:2.0 v/v/v). With a screw-cap, the ship was securely sealed and located within the microwave chamber. The blend was allowed to cool for 30 minutes after the heating process and moved to a separate funnel. The mixture was combined with 10 ml of distilled water, then agitated and allowed to separate. The biodiesel yield was analyzed using gravimetric method. The bottom layer comprising fatty acid methyl esters was drained into a pre-weighed petridish that evaporated[3] in oven overtime at 60^{o}C. The physicochemical properties of tested fuels are given in Table 1.

Table 1 — Physiochemical properties of the fuels

Fuel	Calorific Value (kJ/kg)	Density (kg/m^3)	Kinematic Viscosity (cSt)	Flash Point (°C)	Cetane Index
B20	40123	820	3.6	70	42
B20+50ppm	42700	840	3.6	74	48
B20+100ppm	44742	860	3.8	85	52

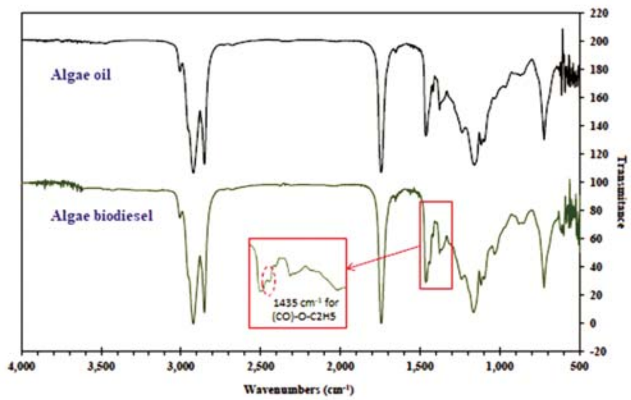

Fig. 1 — FTIR analysis of algae oil and biodiesel

FTIR Analysis of Algae Oil and Biodiesel

Analysis of FTIR has been confirmed as a reliable way of defining the biodiesel quality. From Fig. 1 it is evident that both the source oil FTIR spectra and the prepared biodiesel spectra are significantly similar, provided that the effect did not cause a significant difference in the chemical or functional bonds. Microwave warming's hot-spot result did not trigger undesired response routes. The triacylglycerol was divided into ethyl esters of fatty acids as well as glycerol. For the original oil and biodiesel, the FTIR spectra showed peaks of carbonyl (C = O) at 1745 cm^{-1} and that of C-O at 1164 cm^{-1}, as shown in literature[4], showing that the carbonyl and C-O in the oil are contained in the biodiesel. At 3003, 2854, and 2922 cm^{-1}, the stretching out vibrations of CH, CH_2, as well as CH_3 occur, while the bending vibrations (ρCH_2) of the groups can be identified at 1374, 1164, and 724 cm^{-1}, respectively. A few listed biodiesel peaks appear to be potentially exposed with the spectra's near observance, as shown in Fig. 1. The actual most enormous transesterification effect is to have the new signal at 1435 cm^{-1}, which would be the ethyl ester group, along with its bending vibration.[5]

Experimental Setup

For the fuel testing, a single cylinder diesel engine that distributes a full power of 5.2 kW @ 1500 rpm was used. With the fuel being injected at a set 23° before TDC at a pressure of 220 bar, the engine's working conditions were kept stable. There is a curved chamber with overhead valves in the engine, and the engine's compression ratio is 17.5. An open ECU (Electronic control unit) was used to control the amount of fuel to be pumped. The ECU operated a knob, and the specific amount of alcohol corresponding to the particular voltage was pumped into the engine. To test CO, HC, and NO the AVL 5 Gas Analyser was used. In terms of parts per million, NO and HC were measured, while CO are measured in volume. The specifications used in this engine test[6] are shown in Table 2 & 3.

Table 2 — Engine Specifications

Model	Kirloskar
Cylinders	One
Cooling system	Water-cooled
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5:1
Piston bowl	Hemispherical
Rated Power	5.2 (kW) @ 1500 rpm
Lubrication Oil	SAE 40

Table 3 — Uncertainty of different instruments and parameters

Measurement	Accuracy	% Uncertainty
Load	± 0.1 kg	± 0.2
Speed	± 10 rpm	± 0.1
Burette Fuel measurement	± 0.1 cc	± 1
Time	± 0.1 sec	± 0.2
Manometer	± 1 mm	± 1
CO	± 0.02 %	± 0.2
HC	± 20 ppm	± 0.2
NO	± 10 ppm	± 1
Smoke	± 0.005 FSN	± 0.01
EGT indicator	± 1°C	± 0.15
Pressure pickup	± 0.5 bar	± 1
Crank angle	± 1°	± 0.2

Results and Discussion

CO Emission

CO is a poisonous gas that is odorless, colorless, and tasteless, emitted via the gasoline engines exhaust system of a vehicle that uses diesel as gasoline. The partial combustion process in the engine that results in CO emissions is a waste material generated by the vehicle exhaust. An incomplete combustion process generates CO from any carbon containing fuel. In terms of the load difference, Fig. 2 shows the CO emission variance for each blend. Due to the scarcity of oxygen within the blend, maximum combustion

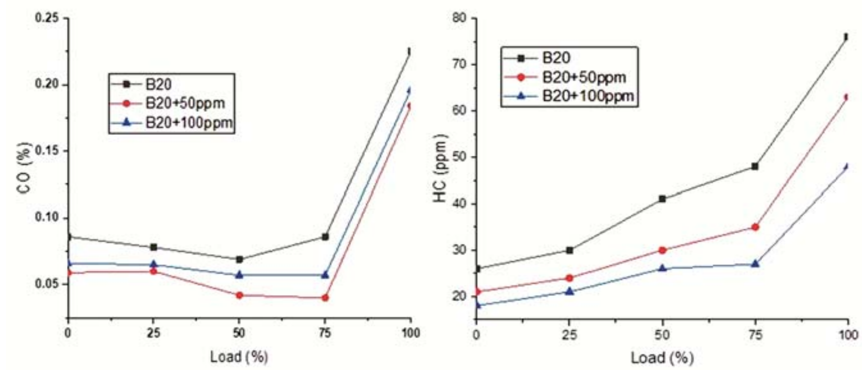

Fig. 2 — Variation of CO and HC emission versus Load

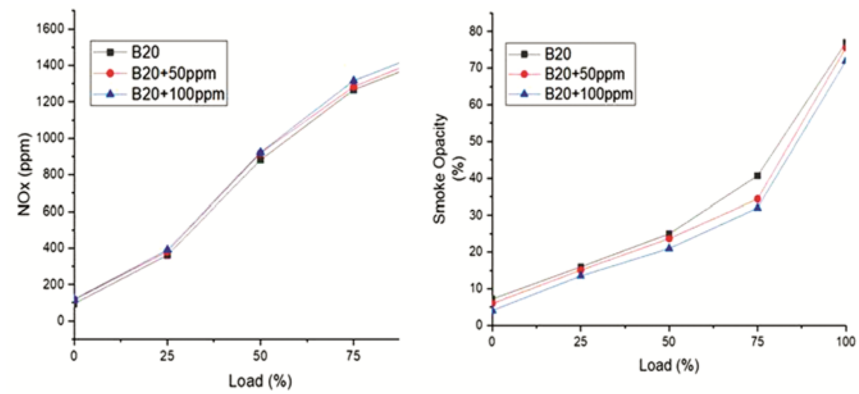

Fig. 3 — Variation of NOx and smoke opacity emission versus Load

support was provided. The CO emission found with the B20 + $TiO_2$100 ppm blend was shown to be deficient emission level.[7]

HC Emission

Homogeneous mixing of fuel with air has allowed reductions in HC emissions. The variance in HC emissions related to the level of loading emissions is given in Fig. 2. From the graph, it is observed that with the increase in the blend ratio of TiO_2 (100 ppm), the HC emission level is marginally reduced. The HC emission of B20 + $TiO_2$100 ppm is lower than that of the B20 blend. The B20 + $TiO_2$100 ppm blend has increased the surface/volume ratio that enables complete combustion. Algae oil acts as a catalyst for oxidation, speeding combustion by improving the oxidation of HCs.[8]

NOx Emission

Oxides of nitrogen are the most dangerous pollutants produced by diesel engines due to high oxygen content of fuel, reaction time and flame temperature. the NOx output of all blends with various load conditions is shown in Fig. 3. This specific improved NOx trend is linked to better oxygen content of blended fuels that results in higher in-cylinder temperatures after the whole mixing at the premixed combustion level. The improved oxygen content of B20 + TiO_2 100 ppm blend raised the gas temperature, which allowed the formation of NOx at high levels.[9]

Smoke Opacity

The smoke opacity for different loads are shown in Fig. 3. The main aspect of smoke will be mainly the fuel-bound oxygen, which suggests that inadequate oxygen is combusted, and long-chain HC thermal cracking results in smoke emissions. In all of the blends at full load conditions, an increase inside the smoke opacity is observed. The smoke emissions from the blending of algae oil biodiesel with B20 + TiO_2 100 ppm are lower than that of B20. This result is consistent with the outcomes of other researchers.[10]

Conclusions

This research aims to supplement diesel fuel in IC engines with affordable algae biofuels with reducing emission characteristics. Therefore to reduce emissions, this research work used nanoadditives. The TiO_2

nanoparticle is added to the B20 fuel, and the engine runs at constant rpm. An experimental test was performed to investigate the effects on various parameters like NOx, HC, CO, and smoke emissions. The TiO_2 nano additives' emission behaviour results in a considerably high reduction in CO, HC, and smoke levels.

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