Emission Control in CI Engines Using Bio-Diesel Fuel Blend and Catalytic Converter

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Abstract- **Efforts are being made throughout the World to reduce the consumption of liquid petroleum fuels wherever is possible. Biodiesel is recently gaining prominence as a substitute for petroleum based diesel mainly due to environmental considerations and depletion of vital resources like petroleum and coal. According to Indian scenario, the demand for petroleum diesel is increasing day by day hence there is a need to find out an appropriate solution. Recently, non edible oil resources are gaining worldwide attention because they can be found easily in many parts of the world especially wastelands that are not appropriate for cultivating food crops, eliminate competition for food, more efficient, more environmentally friendly, produce useful by- products and they are more economical compared to edible oils. Jatropha curcas, Pongamia pinnata, Calophyllum inophyllum,Croton megalo carpus and Azadirachta indica are some of the major non-edible feed stocks for biodiesel production. This paper investigates the potential of Calophyllum inophyllum as a promising feedstock for biodiesel production.In this paper, several aspects such as physical and chemical properties of crude Calophyllum inophyllum oil and methyl ester, fatty acid composition, blending and engine performance and emissions of Calophyllum inophyllum methyl ester were studied. Overall, Calophyllum inophyllum appears to be an acceptable feed stock for future biodiesel production.**

Index Terms- **Emission Control in CI Engines Using Bio-Diesel Fuel Blend and Catalytic Converter.**

INTRODUCTION

The inadequacy of accessible energy resources because of its expanding utilization has driven us to hunt down dependable roots for making alternative fuels. Also, the need to meet the requirements of stringent emission regulations of the government coupled with the need to overcome fuel crisis in the future has forced us to look for alternative sources of fuel. Biodiesels are gaining worldwide acceptance because of the faster depleting petro-diesel fuels. Biodiesels are biodegradable, renewable and more environment friendly than petroleum based fuels. Biodiesel is a renewable and biodegradable fatty acid methyl ester extracted from any kind of vegetable oil and animal fats.

Nowadays, the usage of edible oil from food crops for the production of biodiesel is limited in countries like India, because of their abundant need for domestic purposes which made researchers to narrow down and sharpen their focus of extracting biodiesel from non-edible feedstock. Some of the non-edible oil widely used for the process of biodiesel production are Jatropha carcass, Calophyllum inophyllum, Pongaminapinnata, Ricinus Communis and Ceiba Pent antra. Calophyllum inophyllum fruit and seeds shown in are considered as a suitable feedstock for the production of biodiesel. Some of its advantages over jatropha is that the Calophyllum tree has a high yield of oil of 4560 kg per hectare as compared to oil yield of 1560 per hectare for Jatropha.

CALOPHYLLUM IONOPHYLLUM

Calophyllum inophyllum is a multipurpose tree belonging to the family Clusiaceae, commonly known as mango stein family. This plant has multiple origins including East Africa, India, South East Asia, Australia, and the South Pacific. Calophyllum inophyllum is known by various names around the world.It grows in areas with an annual rain of 1000–5000mm at altitudes from 0 to 200m. Calophyllum inophyllum is a low branching and slow-growing tree with two distinct flowering period so flat spring and late autumn. But sometimes its flowering may occur throughout the year. Calophyllum inophyllum grows best in sandy, well drained soils. However it tolerates , calcareous, and rocky soils. The tree supports a dense canopy of glossy, elliptical, shiny and tough leaves, fragrant white flowers, and large round nuts. Its size typically ranges between 8 and 20m (25–65 ft)tall at maturity, sometimes reaching upto 35m(115ft). The growth rate of the tree is1m(3.3ft)in height per year on good sites. Its leaves are heavy and glossy,10–20 cm(4–8 in.)long and 6–9 cm(2.4–3.6 in.)wide, light green when young and dark green when older.Fruits are spherical drupes and arranged in clusters. The fruit is reported to be pinkish green at first; however, it turns later to be bright green and when ripe, it turns dark grey- brown and wrinkled.The tree yield is 100–200 fruits/kg. In each fruit, one large brown seed2–4 cm(0.8–1.6in.)in diameter is found. The trees yield 3000–10,000seeds/tree/season. The seed is surrounded by a shell and a thin layer of pulp of 3–5 mm. Calophyllum inophyllum oil is non-edible and dark green. Traditionally, its oil has been used as a medicine, soap, lampoil, hair grease and cosmetic in different parts of the world. Recently, Calophyllum inophyllum has been proposed as a source of biodiesel. the feedstock and the obtained biodiesel is blended with diesel in the proportion of CIME30, CIME60 and CIME100 for engine testing. The performance, emission and combustion characteristics of different blends of CIME biodiesel are compared to those of the fossil fuel diesel and the results are summarized.

LITERATURE SURVEY

K. Dinesh [1] Tamanu biodiesel has emissions generally close to diesel like HC and some lower than the diesel like CO and NOx study shows that B10 has better efficiency and emissions are also reduced when compared to the other blend properties.

A.E.Atabani a,b,n, AldaradaSilvaCesar [2] The summary of engine performance and emission results of Calophyllum inophyllum methyl ester(CIME)showed different trends. Some studies reported that higher percentage of biodiesel tend to decrease brake power, torque, CO and HC and increase BSFC and NOx.

B. Ashok, K. Nanthagopal , D. Sakthi Vignesh[3] Calophyllum inophyllum methyl ester has been obtained from the feedstock and the obtained biodiesel is blended with diesel in the proportion of CIME30, CIME60 and CIME100 for engine testing. The performance, emission and combustion characteristics of different blends of CIME biodiesel are compared to those of the fossil fuel diesel and the results are summarized.

Mohan T Raj and Murugumohan Kumar K Kandasamy [3] the project aims to evaluate the suitability of using biodiesel as an alternative fuel in VCR engine. Experimental investigations were carried out on the operating characteristics of the engines.

Department of Thermal Engineering, Christ the King Engineering College, Coimbatore, Tamil Nadu, India [5], From this project the author explains that the analysis developed a two stage esterification procedure to produce biodiesel from Tamanu oil. The specific fuel consumption is slightly lower than diesel for B10, B20 but closer to diesel when increase the load. Blends up to 30% substantially reduce CO2 emissions with a marginal increase in brake thermal efficiency and also it decreases the HC, and NOx emissions with increase in load. Experimental Investigations show that blending of Tamanu methyl esters up to 30 % (B30) with diesel for use in an unmodified diesel engine is viable and it reduces the harmful emissions.

Murugan K, Udhayakumar K [6], the qualities of biodiesel produced from edible and non edible oil are comparable with diesel fuelIt is also observed that the specific gravities of vegetable oil methyl esters are slightly higher than that of diesel fuel. As they are slightly heavier than diesel fuel hence their viscosities are also little higher than that of diesel fuel.

K. Dinesh, A. Tamilvanan, S. Vaishnavi, M. Gopinath & K.S. Raj Mohan [7], The study shows that B10 has better efficiency and emissions are also reduced when compared to the other blend properties. Efficiency is high in the B10 blend Tamanu oil as the oxygen content excess which is inbuilt and reduces emissions such as HC, CO and NOX. Tamanu oil can be a good substitute for diesel in renewable applications. To enhance the combustion properties and emission control in the IC engine are basic criteria for the future scope in the Tamanu based biodiesel production.

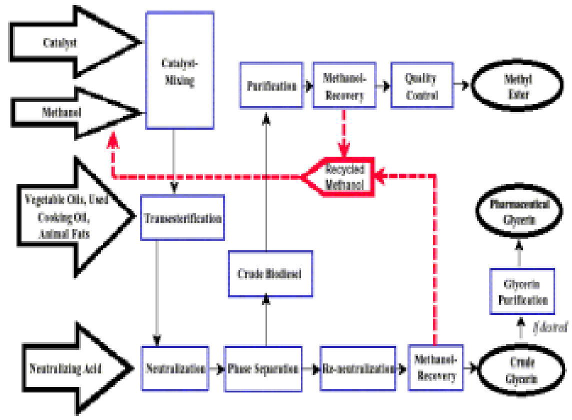
BIODIESEL PRODUCTION

As mentioned above biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste oils. There are three basic routes to biodiesel production from oils and fats:

- Base catalysed transesterification of the oil.
- Direct acid catalysed Transesterification of the oil.
- Conversion of the oil to its fatty acids and then to biodiesel.

Almost all biodiesel is produced using base catalysed transesterification as it is the most economical process requiring only low temperatures and pressures and producing a 98% conversion yield. For this reason only this process will be described in this report. The Transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerine molecule as its base with three long chain fatty acids attached. The characteristics of the fat are determined by the nature of the fatty acids attached to the glycerine. The nature of the fatty acids can in turn affect the characteristics of the biodiesel. During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide or potassium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel and crude glycerol. In most production methanol or ethanol is the alcohol used (methanol produces methyl esters while ethanol produces ethyl esters) and is base catalysed by either potassium or sodium hydroxide. Potassium hydroxide has been found to be more suitable for the ethyl ester biodiesel production, while either base can be used for the methyl ester.

A common product of the transesterification process is the Oil Methyl Ester (OME) produced from raw oil reacted with methanol. The figure below shows the chemical process for methyl ester biodiesel. The reaction between the fat or oil and the alcohol is a reversible reaction and so the alcohol.



Esterification of vegetable oil

A known amount of oil was taken in the above mentioned setup. Heat is supplied to the setup using a heating mantle. A known amount of sulfuric acid in methanol was added to the oil and stirred continuously maintaining a steady temperature of 640C. Reaction continued for two hours. Intermittently samples were collected at regular intervals (30 min) and acid values were determined. After the confirmation of completion of the reaction by measuring the acid value of the sample, which should be between 0.1 and 0.5, the heating was stopped and the products were cooled. The un-reacted methanol was separated by distillation. The remaining product is further used for transesterification to obtain methyl esters. The organic layer after neutralizing with 10% NaOH solution, the excess methanol present in the reaction was distilled out. Vacuum was applied to remove the moisture in the sample.

The methyl ester was refined with NaOH solution the reaction temperature was maintained at 60oC for 30 minutes. The refined sample was further cooled and centrifuged to remove residual soap. The organic layer was washed with hot water to neutral Ph. The washed samples was further dried and determined for FFA. The methyl further analysed for determining the properties as per ASTM standards. Bound glycerol estimation was performed on the methyl esters to find the unconverted oil. The methyl esters were found to be about 98 % in all the experiments.

Types of catalytic converter

Two-way

A two-way (or "oxidation") catalytic converter has two simultaneous tasks:

Oxidation of carbon monoxide to carbon dioxide: $2CO + O_2 \rightarrow 2CO_2$

Oxidation of hydrocarbons (unburnt and partially burnt fuel) to carbon dioxide and water: $C_xH_{2x+2} + [(3x+1)/2]\ O_2 \rightarrow xCO_2 + (x+1)\ H_2O$ (a combustion reaction)

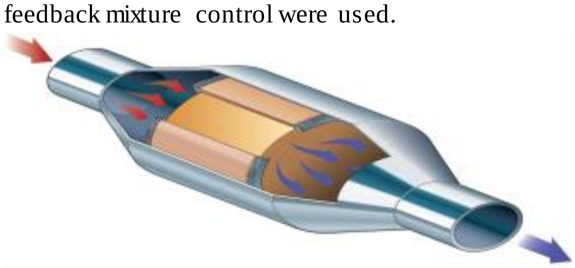
This type of catalytic converter is widely used on diesel engines to reduce hydrocarbon and carbon monoxide emissions. They were also used on gasoline engines in American- and Canadian-market automobiles until 1981. Because of their inability to control oxides of nitrogen, they were superseded by three-way converters. The reduction and oxidation catalysts are typically contained in a common housing, however in some instances they may be housed separately. A three-way catalytic converter has three simultaneous tasks:

Reduction of nitrogen oxides to nitrogen and oxygen: $2NO_x \rightarrow xO_2 + N_2$

Oxidation of carbon monoxide to carbon dioxide: $2CO + O_2 \rightarrow 2CO_2$

Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water: $C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO_2 + (x+1)H_2O$.

In general, engines fitted with 3-way catalytic converters are equipped with a computerized closed-loop feedback fuel injection system using one or more oxygen sensors, though early in the deployment of three-way converters, carburetors equipped for feedback mixture control were used.



Three Way:

Three-way catalytic converters can store oxygen from the exhaust gas stream, usually when the air-fuel ratio goes lean. When insufficient oxygen is available from the exhaust stream, the stored oxygen is released and consumed. A lack of sufficient oxygen occurs either when oxygen derived from NOx reduction is unavailable or when certain maneuvers such as hard acceleration enrich the mixture beyond the ability of the converter to supply oxygen.

Unwanted reactions can occur in the three-way catalyst, such as the formation of odoriferous hydrogen sulfide and ammonia. Formation of each can be limited by modifications to the wash coat and precious metals used. It is difficult to eliminate these byproducts entirely. Sulfur-free or low-sulfur fuels eliminate or reduce hydrogen sulfide.

Reduction of nitrogen oxides to nitrogen (N_2)

$2\ CO + 2\ NO \rightarrow 2\ CO_2 + N_2$

hydrocarbon + NO $\rightarrow CO_2 + H_2O + N_2$

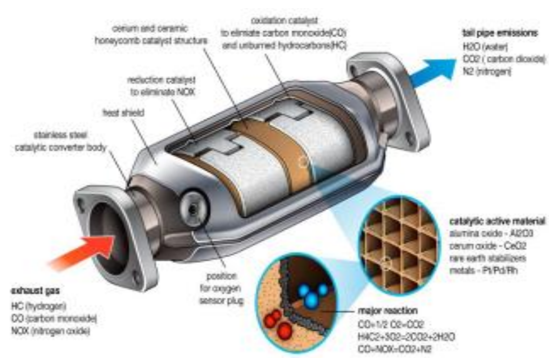
$2\ H_2 + 2\ NO \rightarrow 2\ H_2O + N_2$

Oxidation of carbon monoxide to carbon dioxide

$2\ CO + O_2 \rightarrow 2\ CO_2$

Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water, in addition to the above NO reaction hydrocarbon + $O_2 \rightarrow H_2O + CO_2$

These three reactions occur most efficiently when the catalytic converter receives exhaust from an engine running slightly above the stoichiometric point. For gasoline combustion, this ratio is between 14.6 and 14.8 parts air to one part fuel, by weight. Three-way converters are effective when the engine is operated within a narrow band of air-fuel ratios near the stoichiometric point, such that the exhaust gas composition oscillates between rich (excess fuel) and lean (excess oxygen). Conversion efficiency falls very rapidly when the engine is operated outside of this band. Under lean engine operation, the exhaust contains excess oxygen, and the reduction of NOx is not favored. Under rich conditions, the excess fuel consumes all of the available oxygen prior to the catalyst, leaving only oxygen stored in the catalyst available for the oxidation function.



RESULTS AND DISCUSSION

ENGINE DETAILS:

ICENGINE SET UP UNDER TEST IS RESEARCH DIESEL HAVING POWER 3.50 KW @ 1500 RPM WHICH IS 1 CYLINDER, FOUR STROKE , CONSTANT SPEED, WATER COOLED, DIESEL ENGINE, WITH CYLINDER BORE 87.50(MM), STROKE LENGTH 110.00(MM), CONNECTING ROD LENGTH 234.00(MM), COMPRESSION RATIO 18.00, SWEPT VOLUME 661.45 (CC)

Combustion Parameters :

Specific Gas Const (kJ/kgK) : 1.00, Air Density (kg/m^3) : 1.17, Adiabatic Index : 1.41, Polytrophic Index : 1.28, Number Of Cycles : 5, Cylinder Pressure Referance : 4, Smoothing 2, TDC Reference : 0

Performance Parameters:

Orifice Diameter (mm): 20.00, Orifice Coeff. Of Discharge: 0.60, Dynamometer Arm Length (mm) : 185, Fuel Pipe dia (mm) : 12.40, Ambient Temp. (Deg C) : 27, Pulses Per revolution : 360, Fuel Type : Diesel, Fuel Density (Kg/m^3) : 851, Calorific Value Of Fuel (kj/kg) : 43290.

Emissions

There are various emissions which come out as by product while combustion occurs in a diesel engine. The main gases which emit outside are Carbon monoxide, Nitric Oxide, Hydro carbons, Particulate matters.

From this the gases like Carbon monoxide Nitric oxides are very much dangerous gases when compared to other gases. Its not the fact that Hydrocarbons will not cause any effect. But its little inefficient while compared to carbon monoxide and nitric oxide.

Effects of gases:

- (NO)X - Bronchospasm, bronchitis ,asthma.
- (CO) - Reduces the ability of Hemoglobin.
- (HC) - Irritation of eye , respiratory irritation.

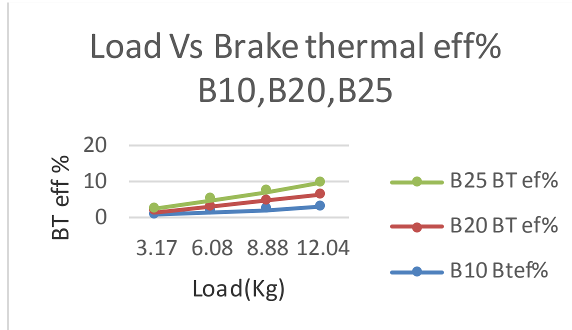


Figure 1:Load Vs BTeff.%

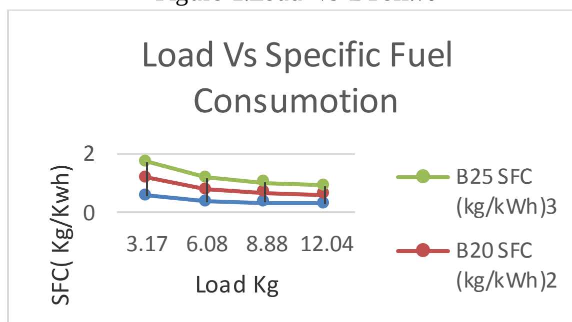


Figure 2: Load Vs Specific Fuel Concumption

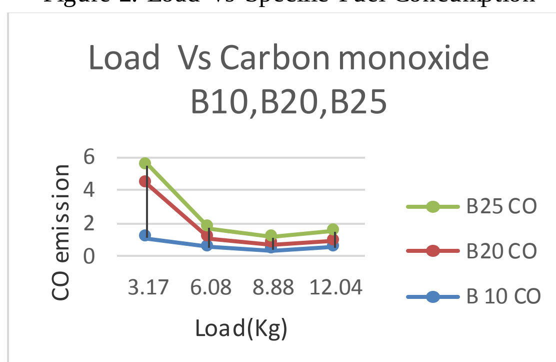


Figure 3 Load Vs Carbon Monoxide

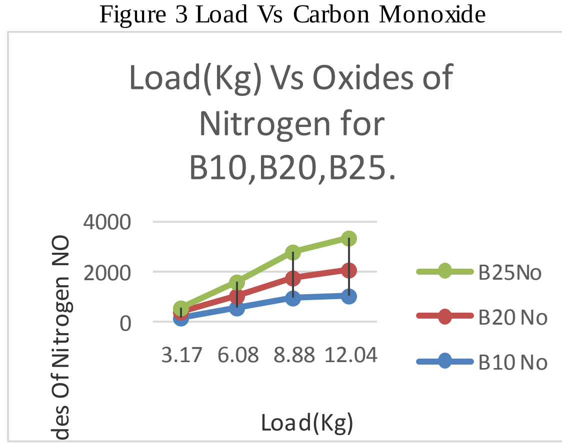


Figure 4Load VsNitric Oxides

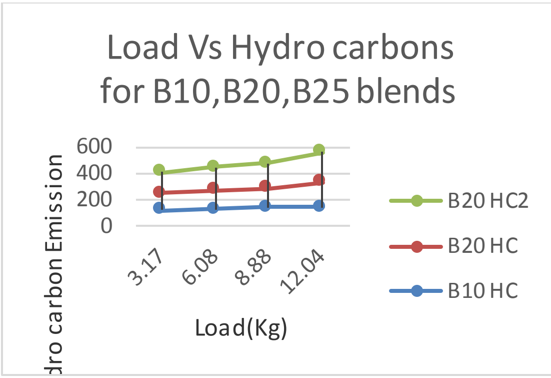


Figure 5 Load Vs Hydrocarbons

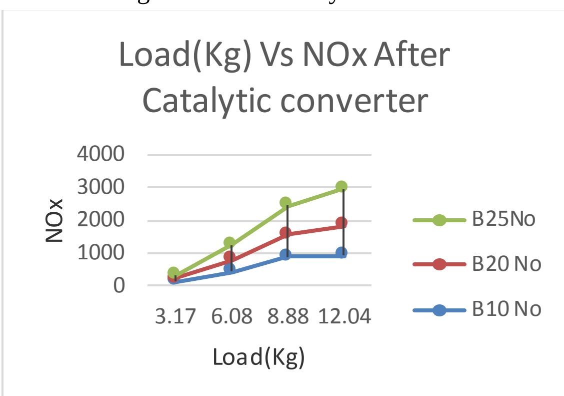


Figure 6 Load Vs NOx after Catalytic converter.

After using catalytic converter in the engine there is a slight changes in the emission of NOx because catalytic converter has a reducing action against nitric oxide.Hence if we use catalytic converters in an engine we can reduce NOx at a larger level.

CONCLUSION

From this work we can conclude that bio-diesel can be used as promisable feedstock fuels. Crude Calophyllum inophyllum oil was reported to be highly acidic.

Therefore, a two-step of acid–base catalysed transesterification process was used to produce biodiesel from this feedstock.. Therefore higher percentage of biodiesel tends to decrease in brake power and torque.

Tamanu biodiesel has emissions generally close to diesel like HC and some lower than the diesel like CO and NOx. Hence B10 blend of biodiesel is very much effective when compared to B20 and B25 blends.

Efficiency is high in the B10 blend Tamanu oil as the oxygen content excess which is inbuilt and reduces emissions such as HC, CO and NOX. Tamanu oil can be a good substitute for diesel in renewable applications.

Also the use of Catalytic converter in the exhaust manifold thus reduces the emission content of Nitric Oxide. Nitric oxide emission is very higher in using Bio-diesel blends in diesel engine.When compared to CO and HC emission nitric oxides emission is greater.Carbon monoxide and Hydrocarbons emissions are very much low in content because of using Biodiesel Blends.

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