Performance Evaluation and Study of Emissions with Biodiesel (Methyl Ester of Cotton Seed Oil)

A. P. Ogale[1], R.S. Patil[2]
[1, 2] Department of Mechanical Engineering
[1, 2] Sinhgad Institute of Technology, Lonavala (M.S.), 410 401, India

Abstract- *Experimental investigation of performance and emission characteristics has been done with methyl ester of cotton seed oil and its blends (10%B, 20%B, 30%, 40%, 50%, 60%, 80% and 100%B) with diesel. Computerised single cylinder four stroke constant speed compression ignition diesel engine test rig was used for experimental investigation. Performance charac teristics include brake thermal efficiency, brake specific fuel consumption, specific energy consumption and exhaust gas temperature. Emission characteristics include CO, HC, CO_2, NOx and smoke density. Methyl ester of cotton seed oil and its blend with diesel shows comparable performance characteristics with neat diesel. There is an improvement in reduction of emissions with increasing blends of methyl ester of cotton seed oil with diesel. The experimental results proved that the use blends of methyl ester of cotton seed oil in compression ignition engine is a viable alternative to diesel.*

Keywords- Cotton seed oil methyl ester, Diesel engine, Diesel engine performance, Exhaust emissions

I. INTRODUCTION

Biodiesel is a renewable, biodegradable and non-toxic fuel. Biodiesel is made from biological sources such as ~~vegetable~~ oils and animal fats. Vegetable oils have comparable energy density, cetane number, heat of vaporization and stochiometric air/fuel ratio with mineral diesel. Numerous studies on the application of biodiesel on diesel engines have been carried out and the results have shown that the performance of engine is comparable to that of using fossil diesel fuel. The emissions from a biodiesel fueled engine are also comparable to or better than that fuelled with fossil diesel fuel.

Crude vegetable oil can be used in CI engine but the large molecular sizes of the component triglycerides result in the oils having higher viscosity compared with that of mineral diesel fuel. The viscosity of liquid fuels affects the flow properties of the fuel such as spray atomization, consequent vaporization and air/fuel mixing [1].

Many investigations revealed that crude vegetable oil as fuel in diesel engine created various problems. Problems were encountered in the early stages of excessive deposits and thickening of lubricating oil in diesel engine. It is reported that these problems may cause important engine failures such as piston ring sticking, injector coking, formation of carbon deposits and rapid deterioration of lubricating oil after the use of vegetable oils for a long period of time [2, 3].

So improving the viscosity of vegetable oil by blending, pyrolysis and emulsification does not solve the problem completely [4, 5]. The alternative way to make use of vegetable oil in the existing diesel engine is their derivatives called monoester and it has been proved that transesterification is the best way to produce ester from vegetable oil [2-10]. This method is applied for producing esters by means of a reaction occurred between vegetable oil (triglyceride) and alcohol in the presence of a catalyst. At the end of the reaction glycerol, an important by-product of transesterification process is formed which is evaluated in pharmaceutical and cosmetics industries [6].

Many researchers found that 100% biodiesel (methyl ester of vegetable oil) experienced lower CO, HC, smoke density and PM emissions while slight increased in CO_2 emission and slight increased or decrease in NOx emissions is realized [11-15].

In the present investigation different parameters for biodiesel production have been investigated. Further, performance and emission characteristics have been investigated and compared with neat diesel fuel and biodiesel mixtures.

II. EXPERIMENTAL

A. Transesterification

Methyl ester of cotton seed oil was made by the process of transesterification. The transesterification of vegetable oil requires three moles of alcohol stochiometrically. However, transesterification is an equilibrium reaction in which excess alcohol is required to drive the reaction close to completion. The chemical reaction of the transesterification process is shown in Fig. 1.

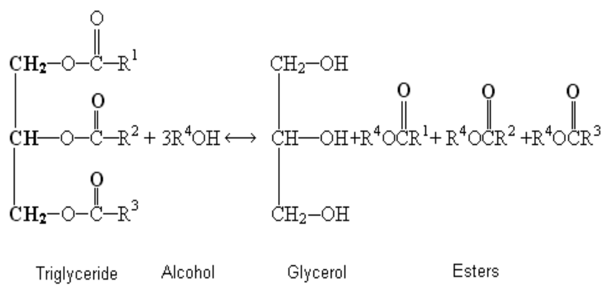

Fig. 1. Schematic representation of transesterification process.

Fig. 2. Experimental setup.

Fig. 3. Emission analyzer (AVL Digas 444).

Cotton seed oil was stirred and heated to 60° to 65° C, mixture of methanol and NaOH was added rapidly under stirred condition. The reaction was continued for two hours at same temperature. Two distinct layers were formed, the lower layer was glycerin and upper layer was ester. The upper layer was separated and moisture was removed from the ester by using calcium chloride.

B. Engine Test

The performance of prepared cotton seed oil methyl ester and its blending (10%, 20%, 30%, 40%, 50%, 60%, 80% and 100%) with diesel was studied in comparison with diesel fuel. The engine used for the study was computerized, single cylinder, four stroke, air cooled, constant speed, direct injection, compression ignition engine. The experimental set up is shown in Fig. 2 and specifications of engine are given in Table I.

The engine is coupled with anemometer, load cell for load measurement, load cell for fuel measurement, rpm transmitter, calorimeter, temperature transmitter. Loading device is rope brake type dynamometer.

The engine was started and allowed to stabilize at no load condition. All readings, load (kg), fuel consumption (gm), rpm, air flow rate (m^3/sec), calorimeter water flow rate (kg/s), temperature of exhaust gas in calorimeter, exhaust gas out from calorimeter, cooling water in calorimeter and temperature of cooling water out from calorimeter were displayed on the computer screen through data acquisition system. The data was logged for no load condition and the calculation table displayed swept volume (m^3/s), actual volume (m^3/s), volumetric efficiency (%), air/fuel ratio, brake power (kw), brake mean effective pressure (bar), brake thermal efficiency (%) and brake specific fuel consumption (kg/kw-min), for no load condition.

Table I: Specification of diesel engine used

General details	Four stroke, single cylinder, air cooled, compression ignition, diesel engine test rig.(Naturally aspirated constant speed engine)
Stroke	0.11 m
Bore	0.08 m
Compression ratio	16.5:1
Rated output	5 HP
Rated speed	1500 rpm
Loading device	Rope brake dynamometer

The load was increased gradually from no load to full load condition (15kg). The load was varied within the interval of 3kg such as, 0kg, 3kg, 6kg, 9kg, 12kg and 15kg. Rope brake type dynamometer was used to load the engine. Load cell measures the value of tension in the rope. All observed data for each load condition were logged and calculated data was stored. Emissions were measured at each load condition from no load to full load condition by using AVL Digas 444 exhaust gas analyzer. The AVL Digass 444 is shown in Fig. 3. The analyzer shows CO, HC, CO_2 and NOx emissions. Smoke density was measured by using smoke meter.

The same procedure was applied for blends of cotton seed oil methyl ester with diesel. Blends are prepared by volume basis. Proper percentage of cotton seed oil methyl ester and diesel was mixed with compressed air for complete mixing. For 10% blending, 10% of cotton seed oil methyl ester on volume basis was taken as compared to neat diesel. For 100ml of diesel 10ml cotton seed oil methyl ester was used for 10% blending. Similar volume basis blends were prepared. Blends used for the study were 10B, 20B, 30B, 40B, 50B, 60B, 80B and 100B.

All the performance and emission characteristics of each blend are compared with neat diesel fuel.

III. ENGINE PERFORMANCE

A. Brake Thermal Efficiency

The variation of brake thermal efficiency with respect to load for different blends and diesel fuel considered for the present analysis is presented in Fig. 4. In each case, brake thermal efficiency increases with load. This is due to increase in power developed with increase in load. The brake thermal efficiency of diesel is found to be maximum (30%) as compared with blends of cotton seed oil methyl ester. 40B gives maximum brake thermal efficiency (28.04%) as compared to other blends. The maximum brake thermal efficiency obtained while using 10B, 20B, 30B, 40B, 50B, 60B, 80B and 100B are respectively 27.53%, 23.69%, 25.87%, 28.04%, 25.29%, 24.78%, 21.13% and 23.50%. At lower loads, brake thermal efficiency of the engine is improved with increasing concentration of the blends as compared with diesel fuel. This is due to the additional lubricity provided by the esters [16]. Excess oxygen in the methyl ester takes part in the combustion process.

It is noticed that after a certain limit, brake thermal efficiency starts decreasing with increasing concentration of blends. This is due to lower calorific value and increase in fuel consumption.

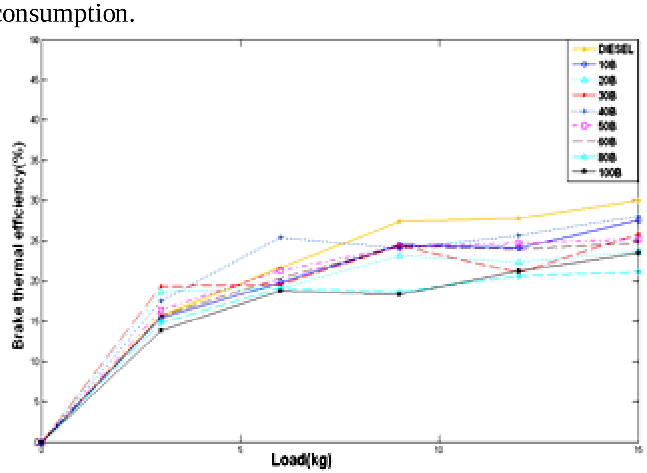

Fig. 4. Brake thermal efficiency of methyl ester of cotton seed oil, its blend and diesel with respect to load.

B. Brake Specific Fuel Consumption

The variation of brake specific fuel consumption with respect to load for different blends and diesel fuel is presented in Fig. 5.

Brake specific fuel consumption is found to be decreases with load for all blends and diesel. This is because of higher increase in brake power with respect to load as compared to the increase in fuel consumption. It is found that at lower load, brake specific fuel consumption of lower concentration of blending is less than that of diesel. Brake specific fuel consumption increases with increase in concentration of blending with respect to load. 40B shows low brake specific fuel consumption at higher load as compared to diesel. Other blend shows higher brake specific fuel consumption than diesel fuel and 40B. 80B and 100B gives higher brake specific fuel consumption than diesel and other blends. This is due to the lower calorific value of blends. Calorific value of blend decreases with increase in concentration of biodiesel.

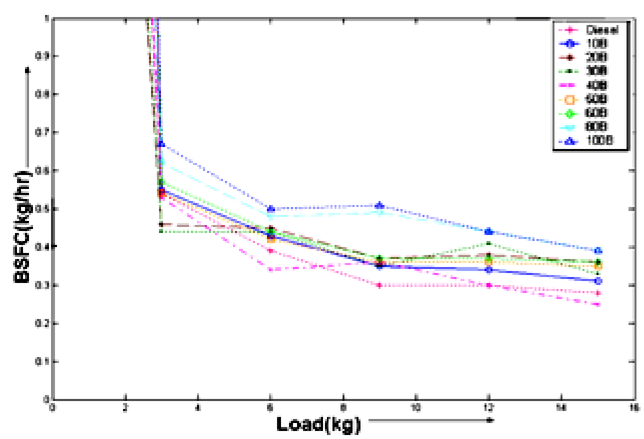

Fig. 5. Brake specific fuel consumption of cotton seed oil methyl ester, its blend and diesel with respect to load.

C. Specific Energy Consumption

The variation of specific energy consumption with respect to load for different blends and diesel fuel is presented in Fig. 6.

It is observed that specific energy consumption of lower concentration of blends (20B to 50B) at lower load is less than that of diesel fuel. This is because of presence of oxygen molecules in the ester. Oxygen molecules help in combustion process and reduce the specific energy consumption [16]. At higher loads, specific energy consumption of all blends and diesel fuel decreases. Specific energy consumption of blends increases with increase in concentration of biodiesel. This is due to lower calorific value of blends with increasing biodiesel concentration and increase in brake power with respect to load. 40B shows lower specific energy consumption than other blends. 80B and 100B shows higher specific energy consumption as compared to other blends and diesel.

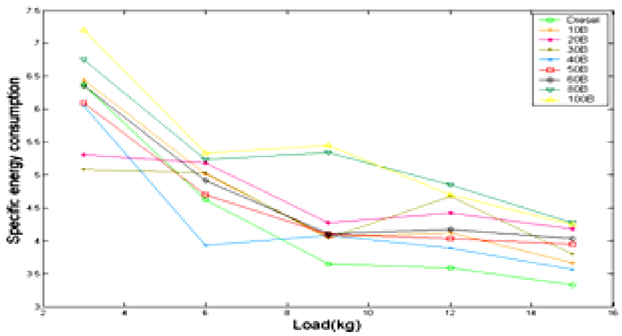

Fig. 6. Specific energy consumption of cotton seed oil methyl ester, its blend and diesel with respect to load.

D. Exhaust Gas Temperature

The variation of exhaust gas temperature with respect load for different blends and diesel fuel is presented in Fig. 7.

At lower loads, all blends shows lower exhaust gas temperature as compared to diesel fuel. At higher loads, exhaust gas temperature increases with concentration of blends. This is because of oxygen molecules in the ester which take part in the combustion process and higher ignition delay in combustion [4, 17]. Higher exhaust gas temperature indicates energy loss from the engine.

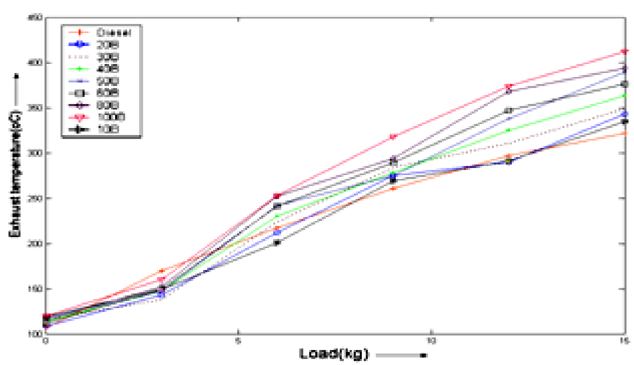

Fig. 7. Exhaust gas temperature of cotton seed oil methyl ester, its blend and diesel with respect to load.

IV. EMISSIONS

A. Carbon Monoxide Emission

The variation of carbon monoxide emission with respect to load is presented in Fig. 8. Carbon monoxide emission increases for all blends of cotton seed oil methyl ester and diesel fuel with increasing loads. This is due to decrease in air/fuel ratio with increasing load on the engine [16, 18]. Higher blends of cotton seed oil methyl ester shows considerable reduction in carbon monoxide emission as compared to lower blends and diesel fuel at all loading condition. This is because of presence of excess oxygen in the ester. This helps in complete combustion of fuel which results in lower CO emission. 30% reduction in CO emission is obtained for 100B.

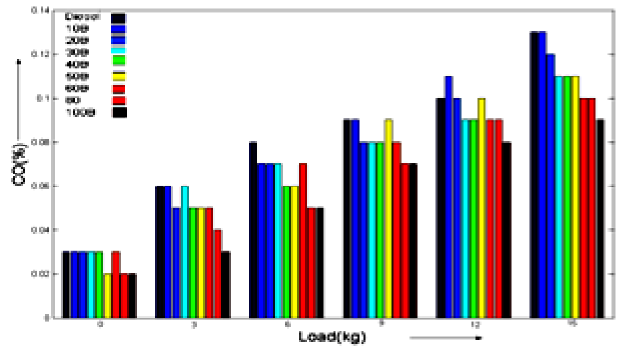

Fig. 8. CO emission of cotton seed oil methyl ester, its blend and diesel fuel with respect to load.

B. Hydrocarbon Emission

The variation of hydrocarbon emission with respect to load for cotton seed oil methyl ester, its blend and diesel fuel is presented in Fig. 9.

Hydrocarbon emission increases for all blends and diesel fuel with load. Higher percentage of blending gives lower HC emission as compared to lower blends and diesel. HC formation is attributed fuel/ air mixtures that are too lean to auto ignite or to support a propagating flame or attributed to fuel/air mixtures that are too rich to auto ignite [19]. Excess oxygen in ester plays important role for reducing HC emissions by better combustion. Low HC emissions show better and complete combustion. About 35% HC emissions are reduced for 100B.

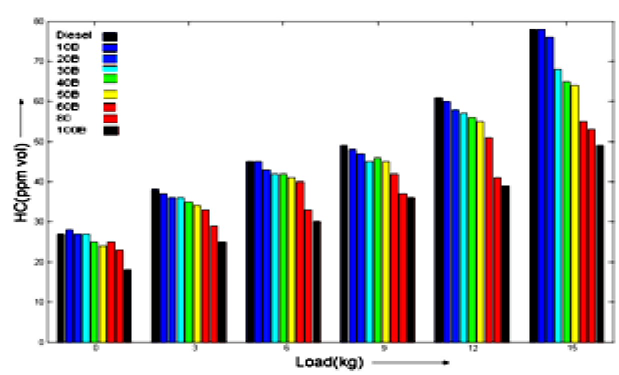

Fig. 9. HC emission of cotton seed oil methyl ester, its blend and diesel fuel with respect to load.

C. Carbon Dioxide Emission

The variation of carbon dioxide emission with respect to load for cotton seed oil methyl ester, its blend and diesel is presented in Fig. 10.

Carbon dioxide emissions increase for increasing blends with increase in loads. All blends of cotton seed oil methyl ester shows higher emission of CO_2 than diesel fuel. This shows that better or complete combustion of blended fuel than diesel.

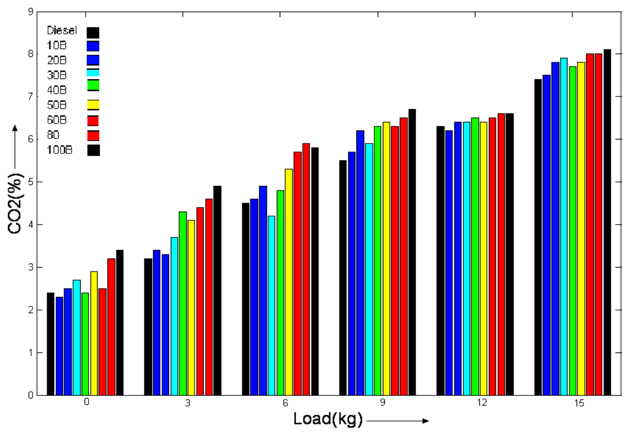

Fig. 10. CO_2 emission of cotton seed oil methyl ester, its blend and diesel fuel with respect to load.

D. NOx Emission

The variation of NOx emission with respect to load is presented in Fig. 11.

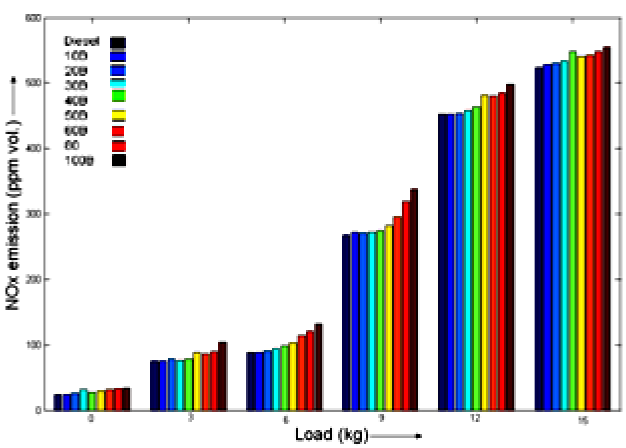

Fig. 11. NOx emission of cotton seed oil methyl ester, its blend and diesel fuel with respect to load.

NOx emission increases with increasing blends of cotton seed oil methyl ester as compared with diesel. It is due to the higher combustion temperature in the engine cylinder caused due to complete combustion higher ignition delay of blended fuel. 5% increase in NOx emission for 100B as compared with diesel fuel is observed.

E. Smoke Density

The variation of smoke density with respect to load is presented in Fig. 12.

There is a wide distribution of fuel/air ratios within in the cylinder for diesel fuel due to its heterogeneous nature of combustion. Smoke emissions are attributed to either fuel/air mixtures that are too lean to auto-ignite or to support a propagating flame or fuel/air mixtures that are too rich to ignite [4, 20, 21]. Presence of oxygen in cotton seed oil methyl ester reduces locally over-rich regions and limit primary smoke formation.

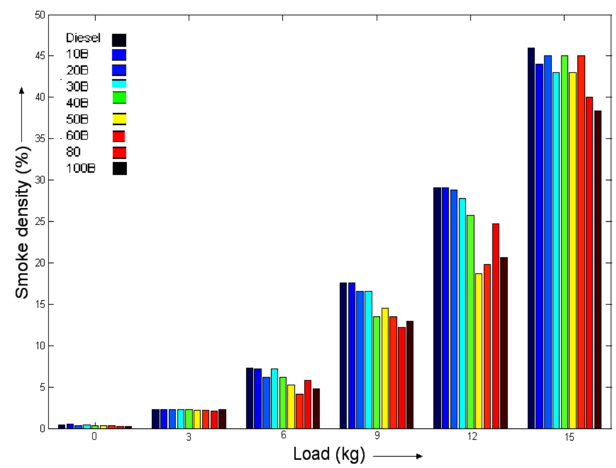

Fig. 12. Smoke density of cotton seed oil methyl ester, its blend and diesel fuel with respect to load.

V. CONCLUSION

The experimental results proved that the use of blends of methyl ester of cotton seed oil in compression ignition engine is a viable alternative to diesel. All blends shows comparable performance characteristics. There is a slight power loss and increase in fuel consumption for all blends of cotton seed oil methyl ester. Brake specific fuel consumption and specific energy consumption increases with increasing concentration of blends as compared with diesel fuel. This is because of decrease in calorific value with increasing concentration of blends. Exhaust gas temperature increases with increase in percentage of blends which results in increase in NOx emissions. Carbon monoxide, hydrocarbon and smoke density reduces as the function of complete combustion due to presence of excess oxygen molecules in biodiesel. Emissions CO, HC and smoke density are reduce to 30%, 35% and 16% respectively while using higher blends as compared to diesel fuel. NOx and CO_2 emissions are increased to 5% and 8% respectively at higher blends as compared to diesel fuel.

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