CERTAIN INVESTIGATION IN A COMPRESSION IGNITION ENGINE USING RICE BRAN METHYL ESTER FUEL BLENDS WITH ETHANOL ADDITIVE

by

Arumugam KRISHNAN[a*], Maran PUNNAIVANAM[b], and Satheeshkumar KOODALINGAM[a]

[a] Department of Mechanical Engineering, University College of Engineering Ramanathapuram, Ramanathapuram, Tamil Nadu, India
[b] Department of Mechanical Engineering, Thiagarajar College of Engineering, Madurai, India

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In this study and analysis, the physical properties such as calorific value, viscosity, flash, and fire point temperatures of rice bran oil methyl ester were found. The rice bran oil biodiesel has been prepared by transesterification process from pure rice bran oil in the presence of methanol and NaOH. Moreover, property enhancement of rice bran oil methyl ester was also made by adding different additives such as ethanol in various proportions. Rice bran oil methyl ester with 1, 3, and 5% ethanol were analyzed for its fuel properties. The effects of diesel-B20ROME blends with ethanol additive of 1, 3, and 5% on a compression ignition engine were examined considering its emissions. It is found that the increase in biodiesel concentration in the fuel blend influences CO_2 and NO_x emissions. On the other hand CO and HC emissions are reduced. It is interesting to observe the emission as ethanol-B20ROME blends, reduces CO_2 and NO_x which are the major contributors to global warming. As the NO_x and CO_2 can be reduced drastically by the proposed blends, the global warming can be reduced considerably.

Key words: *properties, rice bran methyl ester, ethanol, Diesel engine, emissions*

Introduction

Ever increasing cost of petroleum products draws more research in the area of new and renewable energy including biofuel, solar, wind, and hybrid energy systems. Energy is very essential for life quality and social development of people as well as economic growth. Industries are forced to switch new products to meet new and increasing demands. The present researchers have focused on the biofuels to reduce dependence on fossil fuels and to reduce air pollution. The biofuels can play a vital role towards the evolution of a lower carbon economy and also combine the benefits of low greenhouse emissions with the diminution of oil import. High oxidation stability index and good cold flow properties are desirable for combustion of vegetable oil and have been computed for grading the biodiesel of various vegetable oils [1]. The engine can operate without problems, both with rapeseed biodiesel that fuel and with a lot of other biofuels like rice bran oil (RBO) biodiesel and their mixtures [2].

* Corresponding author, e-mail: arumugamk.auucer@gmail.com

Rice bran was used in oil production and mainly used for industrial applications. One of the best ways for the potential utilization of RBO is the production of biodiesel [3]. Shailendra *et al.* [4] investigated production of rice bran oil methyl ester (ROME) with high quality and maximum yield. The influence of raw material composition on properties such as density, viscosity, and higher heating value was developed by a mathematical model to predict the properties [5].

Biodiesels are currently being used in small quantities in various sectors including power, transport, and industry also. The utilization of biodiesel in automobiles significantly reduces emissions of unburned HC, CO, sulphates, polycyclic aromatic HC, nitrated polycyclic aromatic HC, and particulate matter (PM). The use of straight or pure biodiesel (100%) may reduce the CO_2 emissions by more than 75% compared with petroleum diesel. But gel formation in the engine cylinder in cold weather condition and low brake power output lead to the use of blends of biodiesel and additives. In transport sector, 95% diesel with 5% biodiesel has been accepted proportion by the vehicle manufacturers in the world. The increase in production of biodiesel also helps appreciably to increase gross domestic products noticeably in developing countries. The present work is to investigate the improvement in the emission characteristics of ROME blends with fuel additives. No [6] reported that a Diesel engine without any modification would run effectively on a blend of 20% vegetable oil and 80% diesel oil without damaging the engine parts. Hence the blends of diesel oil and ROME with concentrations of 20% (B20) were used as fuels in this work. Gumus [7], observed the results of hazelnut kernel oil methyl ester and its blends with diesel fuel can be used in the engine without any modification and undesirable combustion.

Abolle *et al.* [8] investigated and confirmed the viscosity to be the main physical parameter behind this empirical 30% rule. The viscosity of vegetable oils has been challenging in operating engines and the reduction of viscosity by a simple chemical process is required. Since 1970, considerable efforts have been made by scientists to develop vegetable oil derivatives that approximate the properties and performance of the HC based diesel fuels [9]. Transesterification [10, 11] is the most common method that leads to mono alkyl esters of vegetable oils and fats, now called biodiesel when used for fuel purposes. The vegetable oils have been transesterified to produce biodiesel using methanol and catalysts such as NaOH, KOH, *etc.* This has substantially reduced density and viscosity of the methyl esters.

The use of additives with diesel and biodiesel of vegetable oils has shown improvement in the quality of fuel [10, 12]. Misra and Murthy [12] and Dwivedi and Sharma [13] studied the engine characteristics at cold flow conditions by using biodiesel with additives. Ethanol, 1-propanol, 1-butanol, and di-ethyl ether are commonly used for improving the quality of biodiesel produced. Although biodiesel can be blended with ethanol and diesel fuel, called e-diesel, has at least the same potential to reduce particulate emissions, despite their decreased production cost [14]. From the investigation, it was concluded that the blends with n-butanol would be more suitable to replace pure diesel as the fuel for Diesel engine. The thermal efficiencies of the engine fueled by the blends were comparable with that of fueled by diesel, with slight increase in fuel consumptions, which is due to the lower heating value of ethanol [15].

The HC and NO_x emissions of B20 are, however, still on the higher side. Barabas *et al.* [16] noticed that the utilization of biodiesel-diesel-ethanol in compression ignition (CI) engine decreases the emission. Atabanian *et al.* [17] concluded that the regulated emission, such as those of HC, CO, and PM were reduced through the use of biodiesel and its blends. It is observed that addition of oxygenates have improved the combustion process and lower emissions are obtained. It was observed that the combustion characteristics of the blends of jatropha biodiesel with diesel followed closely with that of the base line diesel and the emissions were decreased other than NO_x [18, 19]. However, an increase in NO_x emissions has been reported through the use of biodiesel and its blends as a fuel in CI engine. Further, Satya *et al.* [20] analyzed, NO_x, were reduced through the use of biodiesel and its blends characteristics by adding additive methanol in ROME.

From the literature reviews and present requirement of alternative fuels we found that biodiesel is used as an alternative fuel in Diesel engines without any modifications in its design. The emission also proved to be environment friendly when compared with diesel emissions. From the studies we have conducted a load test on Kirloskar single cylinder 4-stroke Diesel engine by using biodiesel from vegetable oil resources such as RBO with ethanol as an additive. The addition of ethanol in biodiesel has reduced the NO_x and CO_2 emissions significantly.

Selection of fuel and properties

Biodiesel is the first generation biofuel of biomass which derived from vegetable oils, animals' fats, or recycled restaurant grease for use in diesel vehicles. Biodiesel's physical properties are identical to those of petroleum diesel, but it is a cleaner-burning substitute. Using biodiesel in place petroleum diesel can reduce emissions.

Preparation of biodiesel

Based on the present study, vegetable oil can not be used directly in CI engine for its high viscosity, high density, high flash point, and lower calorific value. So the pure vegetable oil needs to be transformed into biodiesel to obtain the identical properties of diesel fuel. Production of biodiesel is an important process which needs a sustained study and optimization processes. Transesterification is the most popular way to use vegetable oils and reduces the viscosity of the pure vegetable oil by which the atomization characteristics can be improved considerably. In transesterification process one type of alcohol replaces another to produce an ester. An ester is prepared by mixing an alcohol with an acid. The transesterification process is presented in fig. 1.

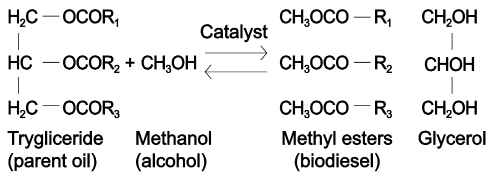

Figure 1. Tranesterification process

From the chemical process, it is found that vegetable oil is an ester of glycerol with long chain fatty acids. The formula for vegetable oil is C_3H_5 (RCOOH)$_3$, with the fatty acids represented by RCOOH attached to a glycerol ($C_3H_5(OH)_3$) molecule. Methanol (CH_3OH) is used to replace glycerol ($C_3H_5(OH)_3$).

Additives

Additives are the substances that could be added to the biodiesel to reduce smoke emissions and to increase the performance efficiency of the engine. It helps to maintain Diesel engine performance by keeping fuel injectors clean and improving fluidity of diesel fuel. Additive can withstand the high temperature of the combustion chamber, not only cleans the engines, but also act as catalysts by reducing consumption of diesel by 6-12% and reduces harmful carbon and particulate emissions substantially. Additives such as n-butanol, ethanol, and di-ethyl ether are normally used. In the present work ethanol is used as an additive due its versatile property and NO_x reduction quality.

Properties of fuel

The property of the biodiesel is an important parameter for determining the fuel property. The physio-chemical properties of fuel are important in design of fuel system for CI engine run on diesel, biodiesel or biodiesel blends or ethanol additive in ROME. We have taken in to account the rice bran biodiesel with ethanol additive. Different blends were used in these works which are:

B100 – 100% biodiesel, B20ROME – 20% biodiesel + 80% petro diesel,

B20E1 – 99% B20ROME and 1% ethanol, B20E3 – 97% B20ROME and 3% ethanol

B20E5 – 95% B20ROME and 5% ethanol.

The physical and chemical properties of vegetable oil, biodiesel, and blend mixtures were found out by standard methods, tab. 1. Different properties such as density, viscosity, calorific value, flash point, fire point, and specific gravity were considered to compare the properties of the fuel with diesel fuel.

Table 1. Properties of the biodiesel

Type of fuel	Flash point [ºC]	Fire point [ºC]	Density [kgm^{-3}]	Calorific value [$kJkg^{-1}K^{-1}$]	Viscosity [mm^2s^{-1}]
Diesel	72	77	832	42414	0.89
B20	188	192	841	41900	0.97
B20E1	74	79	840	41778	3.435
B20E3	73	80	838	41534	3.389
B20E5	71	81	837	41290	3.277

Experimental set-up and experimentation

Experiments have been conducted to run with mechanical dynamometer using biodiesel of RBO and its blend with ethanol additive. The use of neat biodiesel on a large scale is raising certain difficulties and is being adopted in a blended form with petro-diesel fuel and B20 blend has become standardized. Hence by using ROME of 20% with 1, 3, and 5% ethanol has been prepared to for performance and emissions parameters analysis.

Experimental set-up

The experimental set-up used for studying emission characteristics of biodiesel of rice bran is shown in fig. 2. The set-up includes a CI engine, fuel supply system to feed biodiesel, gas analyzer, temperature indicator, and emission display monitor. The details and specifications of the instrument are given further in the paper.

The CI engine used in experimental study is Kirloskar model 4-stroke single cylinder Diesel engines and it is capable of producing 7 horse power. Specifications of the engine are: model is Kirloskar, power – 7 horse power (5.2 kW), speed – 1500 rpm, stroke length – 110 mm, bore diameter – 87.5 mm, and brake drum radius – 0.175 m

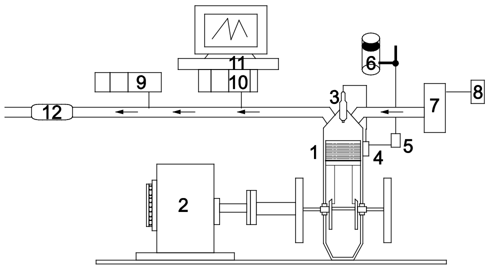

Figure 2. Schematic diagram of experimental set-up; *1 – engine, 2 – dynamometer, 3 – fuel injector, 4 – fuel pump, 5 – fuel filter, 6 – fuel tank, 7 – air tank, 8 – air filter, 9 – smoke meter, 10 – gas analyzer, 11 – monitor, 12 – silencer*

Experiments

The different blends of biodiesels of rice brain oil-diesel with the addition of ethanol at various percentages (1, 3, and 5%) have been taken in to consideration for the performance evaluation. Load testing is carried out to determine a system‘s performance under both normal and accepted peak load conditions. Emissions test is conducted in engine to check the pollutants present in the exhaust gases. The gas analyzer is capable of monitoring the five gases simultaneously that need to be monitored as per the recommendations of Environmental protection agency emissions standards. These gases are CO, HC, CO_2, oxygen, and NO_x.

Several sets of experiments were conducted and the emission characteristics were observed for diesel, B20ROME, B20E1, B20E3, and B20E51. The net load, cooling water temperature, exhaust gas temperature, and time taken for 10 cc of fuel have also been recorded for performance analysis.

Results and discussion

The specific fuel consumption, total fuel consumption, thermal efficiency, and emission levels has been observed and calculated. The results of performance and emissions were discussed.

Results of performance study

The parameters of performance such as total fuel consumption, specific fuel consumption, brake thermal efficiency, indicated thermal efficiency, and mechanical efficiency curves have been plotted between load and various fuel blends of B20ROME with ethanol additives of 1, 3, and 5%.

The total fuel consumption of fuel blends increases with increasing percentage of biodiesel of ROME. The total fuel consumption of B20 biodiesel is slightly higher than diesel fuel. After adding the ethanol additive by 1, 3, and 5% the total fuel consumption is lower than B20ROME and little higher than diesel. Figure 3 shows that the specific fuel consumption (SFC) of fuel blends increases with increasing percentage of biodiesel of ROME. The SFC of B20ROME biodiesel is slightly higher than diesel fuel. After blending the ethanol additive by 1, 3, and 5% the total fuel consumption is lower than B20 and little higher than diesel.

Figure 4 shows that the brake thermal efficiency of fuel blends decreases slightly and its efficiency is close to diesel fuel. The brake thermal efficiency of diesel at full load is 28.26% and is little lower for B20ROME about 26.77%. The brake thermal efficiency of fuel B20ROME after adding the ethanol additive by 1, 3, and 5% increases with increasing additive and is close to diesel fuel by 27.64, 26.32, and 27.29%. Figure 5 shows that the mechanical efficiency of fuel blends decreases slightly and close to the diesel fuel efficiency. The me-

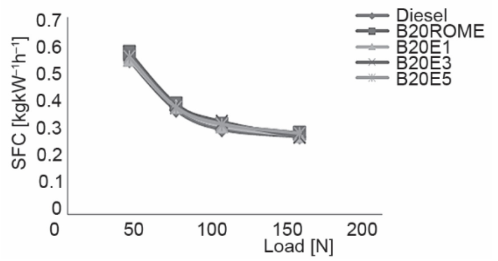

Figure 3. Specific fuel consumption *vs.* load

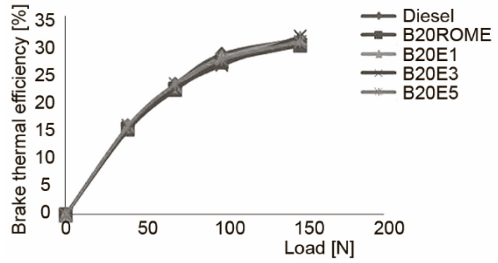

Figure 4. Brake thermal efficiency *vs.* load

chanical efficiency of diesel at full load is 63.24% and is little lower and very similar for B20ROME about 63.14%. The mechanical efficiency of fuel B20ROME after adding the ethanol additive by 1, 3, and 5% decreases with increasing in additive and is close to diesel fuel by 61.32, 61.04, and 61.79%.

Figure 6 shows that the indicated thermal efficiency of fuel blends increases slightly and very close to the diesel fuel efficiency. The indicated thermal efficiency of diesel at full load is 48.91% and is little lower for B20ROME about 47.24%. The indicated thermal efficiency of fuel B20ROME after adding the ethanol additive by 1, 3, and 5% increases with increasing additive by 50.72, 51.37, and 49.22%. From the performance analysis it was concluded that the efficiency of the biodiesel of ROME 20% is little lower than that of diesel. The addition of ethanol by 1, 3, and 5% in B20ROME increases the performance and it is observed to be very close to diesel fuel.

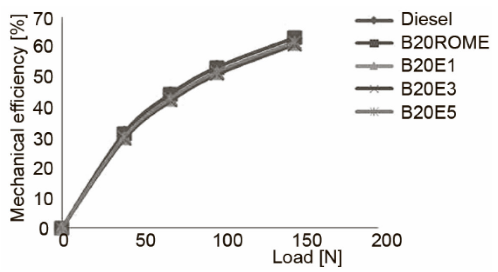

Figure 5. Mechanical efficiency *vs.* load

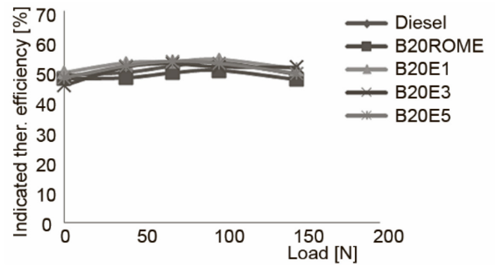

Figure 6. Indicated thermal efficiency *vs.* load

Results of emission study

The emission results found during the experiments have been plotted and discussed for various biodiesel blends such as B20E1, B20E3, and B20E5.

It can be observed that HC emission of diesel, biodiesel, B20E1, B20E2, and B20E5 in fig. 7. It is found that HC emission of diesel turns up higher when compared to biodiesel. The HC emission of B20E1 is higher comparing to B20ROME. The emission in case of depicting B20E1, B20E2, and B20E5 appears high and it seems slightly analogous to diesel while comparing the efficiency of biodiesel. Figure 8 shows reduced CO emissions of diesel and biodiesel remains the same, whereas CO emission of B20E1 gradually increases. The CO emission increases with further increase of ethanol additive by 3% and 5%. There is a slight variation in CO emission of B20E3 and the emission is comparatively lower than CO emission of B20E5.

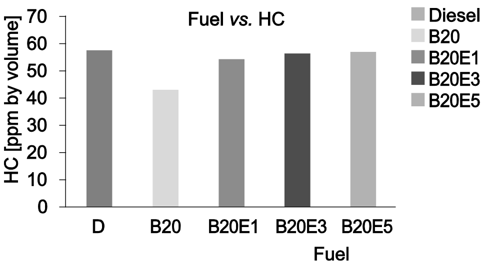

Figure 7. The HC emission of B20ROME with 1, 3, and 5% of ethanol

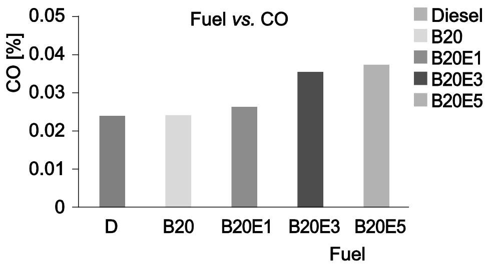

Figure 8. The CO emission of B20ROME with 1, 3, and 5% of ethanol

However, the emission of CO_2 and reveals that the CO_2 emission of biodiesel is higher when compared to the rest of the fuels and there is a gradual increase in the emission process when using B20E1, B20E3, and B20E5, but the emission level is lower while comparing to biodiesel and there is a slight increase when considering the case of diesel, fig. 9. In fig. 10 one can observe that NO_x emissions are increased with the fuel blends of higher concentrations of rice bran biodiesel in diesel oil. Moreover NO_x emission decreases when B20E1 blend is used and there is a slight variation in the decreasing level in case of using B20E3 and it remains same while applying B20E5.

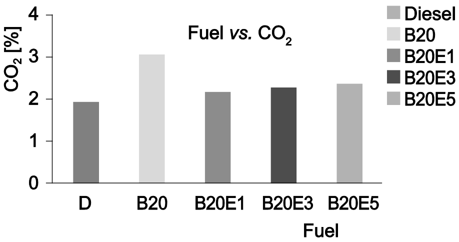

Figure 9. The CO_2 emission of B20ROME with 1, 3, and 5% of ethanol

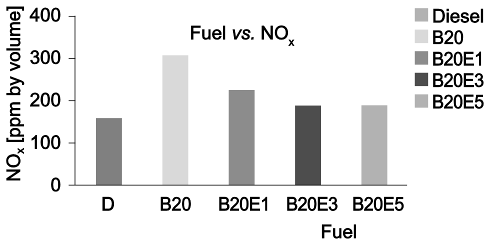

Figure 10. The NO_x emission of B20ROME with 1, 3, and 5% of ethanol

Conclusions

Adding ROME in diesel slightly decreases the brake thermal efficiency of engine, however, the addition of ethanol by 1, 3, and 5%, the performance of the engine increases than the performance of B20ROME and it is close to the diesel oil. Though the addition of ROME and ethanol increases the fuel consumption, its emission levels are satisfactory. Adding ROME in diesel increases the CO_2 in B20ROME. Conversely, CO_2 emission was reduced with the addition of ethanol at the concentrations 1, 3, and 5% to B20 ROME blend. For B20ROME alone, CO emission reveals low variation. However, after ethanol was added to B20ROME blend, CO emission was increased proportionally. A slender reduction of HC emissions was observed as ROME was added to diesel fuel. The addition of ethanol in B20ROME increases the HC emission and close to the diesel fuel.

The NO_x emissions were increased for fuel blend B20 compared to diesel oil. With the addition of ethanol by 1, 3, and 5% to B20ROME, the NO_x emission levels were reduced significantly to that of B20ROME. Hence the addition of ethanol in biodiesel of RBO-diesel oil blends can be used to control NO_x emissions which reduces CO_2 concentration, thereby the impact of global warming would be reduced. Finally it is concluded that the addition of 1, 3, and 5% ethanol in B20ROME offers a fair performance and low NO_x emission. Therefore, the addition of ethanol with RBO biodiesel is favorable for any Diesel engine at various operating conditions.

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