Performance characteristics assessment of biodiesel blends prepared from waste cottonseed oil

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Abstract

There is an increasing interest in India to search for suitable alternative fuels that are environmental friendly. The use of biodiesel is rapidly expanding around the world, making it imperative to fully understand the impacts of biodiesel on the diesel engine combustion process and pollutant formation. The present study deals with the study performance characteristics of a diesel engine with neat diesel fuel and biodiesel mixtures was carried out. Waste cottonseed oil was selected for biodiesel production. The transesterification results showed that with the variation of catalyst, methanol, variation of biodiesel production was realized. A maximum of 76% biodiesel was produced with 20% methanol in presence of 1.0% KOH. The result also shows that the exhaust emissions including carbon monoxide (CO), hydrocarbons (HC) and smoke emissions were reduced for all biodiesel mixtures and hydrocarbon (HC) and NO_x emissions of B10 blend is lowest among all the three blends

Keywords: cottonseed oil, Bio diesel, properties, Blends

1. Introduction

Petroleum resources are finite and therefore search for alternative is continuing all over the world. The major energy demand is fulfilled from the conventional energy resources like coal, petroleum and natural gas. Petroleum-based fuels are limited reserves concentrated in certain regions of the world. These sources are in the verge of getting extinct. The scarcity of known petroleum reserves will make renewable energy resources like biodiesel more attractive. Bio- fuels like ethanol and bio-diesel being environment friendly, will help us to conform to the stricter emission norms [1]. International experience has demonstrated the advantages of using ethanol and methanol as automotive fuel. Since blends below 20% of biodiesel do not present any problem and reduce harmful emission. The gases emitted by petrol and diesel driven vehicles have an adverse effect on the environment and human health. There is universal acceptance of the need for reducing such emissions by adopting ways to reduce emission without affecting the process of growth and development. One of the ways in which this can be achieved is through the use of biodiesel and blending them with diesel. With domestic crude oil output stagnating, the momentum of growth experienced a quantum jump since 1990s when the economic reforms were introduced paving the way for a much higher rate of development leading the demand for oil to continue to rise at an ever increasing pace. The situation offers us a challenge as well as an opportunity to look for substitutes of fossil fuels for both economic and environmental benefits to the country. Biofuels are generally considered as offering many priorities, including sustainability, reduction of greenhouse gas emissions, regional development, social structure and agriculture and security of supply. In developed countries there is a growing trend towards employing modern technologies and efficient bioenergy conversion using a range of biofuels, which are becoming cost-wise competitive with fossil fuels. The scarcity of conventional fossil fuels, growing emissions of combustion generated pollutants and their increasing costs will make biomass sources more attractive [2]. The kinematic viscosity of vegetable oils is about an order of magnitude greater than that of conventional, petroleum-derived diesel fuel. High viscosity causes poor atomization of the fuel in the engine's combustion chambers and ultimately results in operational problems, such as engine deposits. Since the renewal of interest during the late 1970s in vegetable oil derived fuels, four possible solutions to the problem of high viscosity have been investigated: transesterification, pyrolysis, dilution with conventional petroleum-derived diesel fuel, and micro emulsification. Transesterification is the most common method and leads to monoalkyl esters of vegetable oils and fats, now called biodiesel when used for fuel purposes [3]. Briefly, it consists of reacting the vegetable oil feedstock with an alcohol, usually methanol, in the presence of a catalyst, usually a base such as sodium or potassium hydroxide, to give the corresponding vegetable oil (usually methyl) esters. Methyl esters are the most common form of biodiesel, largely due to methanol being the least expensive alcohol. The high viscosity of vegetable oils as a major cause of poor fuel atomization resulting in operational problems such as engine deposits was recognized early. Although engine modifications such as higher injection pressure were considered, reduction of the high viscosity of vegetable oils usually was achieved by heating the vegetable oil fuel. Often the engine was started on petro diesel and, after a few minutes of operation, was then switched to the vegetable oil fuel, although a successful cold-start on high-acidity peanut oil was reported. Advanced injection timing was a technique also employed. Seddon gives an interesting practical account about a truck that operated successfully on different vegetable oils using preheated fuel [4].

2. Literature Review

Standardization of transesterification process parameters for the production of methyl ester of filtered neem oil and fuel characterization for engine performance. It was found that filtered neem oil at 6:1 M ratio (methanol to oil) preheated at 55°C temperature and maintaining 60°C reaction temperature for 60 min in the presence of 2 percent KOH and then allowed to settle for 24 h in order to get lowest kinematic viscosity (2.7 cSt) with ester recovery (83.36%) [5]. Alternative fuels for diesel engines have been becoming increasingly important due to diminishing petroleum reserves and the growing environmental concerns have made renewable fuels an exceptionally attractive alternative as a fuel for the future. Biodiesel is derived from a varied range of edible and inedible vegetable oil, animal fats, used frying oil and waste cooking oil. The edible oil in use at present is soyabean, sunflower, rapeseed and palm. The inedible oil used as feedstock for biodiesel production includes J. curcas, M. indica, F. elastica, A. indica, C. inophyllum jatropha, neem, P. pinnata, rubber seed, mahua, silk cotton tree, waste cooking, microalgae, etc. Transesterification is a chemical reaction between triglyceride and alcohol in the presence of catalyst or without catalyst [6]. The purpose of the transesterification process is to lower the viscosity of the oil. Methanol being cheaper is the commonly used alcohol during transesterification reaction. Homogeneous catalysts such as sulphuric acid, sodium hydroxide, potassium hydroxide and heterogeneous catalysts such as calcium oxide, magnesium oxide and others can be used in transesterification reaction [7]. Non-catalysed transesterification processes are the BIOX process and the supercritical alcohol (methanol) process. The advantage in its usage is attributed to lesser exhaust emissions in terms of carbon monoxide, hydrocarbons, particulate matter, polycyclic aromatic hydrocarbon compounds and nitrated polycyclic aromatic hydrocarbon compounds [8]. The main advantages of biodiesel given in the literature include its domestic origin, its potential for reducing a given economy's dependency on imported petroleum, biodegradability, high flash point, and inherent lubricity in the neat form. The biodiesel policy will help reducing of petroleum imports and saving of foreign exchange. The biodiesel high flash point makes it possible for its easy storage and transportation. The main disadvantages of biodiesel are its higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide emissions, lower engine speed and power, injector coking, engine compatibility, and high price. Blends of up to 20% biodiesel mixed with petroleum diesel fuels can be used in nearly all diesel equipment and are compatible with most storage and distribution equipment. Biodiesel can be used directly or as blends with diesel fuel in a diesel engine [9]. Biodiesel is a biodegradable and renewable fuel. It contributes no net carbon dioxide or sulphur to the atmosphere and emits less gaseous pollutants than normal diesel. Carbon monoxide, aromatics, polycyclic aromatic hydrocarbons (PAHs) and partially burned or unburned hydrocarbon emissions are all reduced in vehicles operating on biodiesel [10]. Recently, biodiesel has been receiving increasing attention due to its less polluting nature and because it is a renewable energy resource as against the conventional diesel, which is a fossil fuel leading to a potential exhaustion. Biodiesel has become more attractive recently because of its environmental benefits [11]. Biodiesel is an environmentally friendly fuel that can be used in any diesel engine without modification. Biodiesel fuels have generally been found to be nontoxic and are biodegradable, which may promote their use in applications where biodegradability is desired. Neat biodiesel and biodiesel blends reduce particulate matter (PM), hydrocarbons (HC) and carbon monoxide (CO) emissions and slightly increase nitrogen oxides (NOx) emissions compared with petroleum-based diesel fuel used in an unmodified diesel engine. The brake power of biodiesel was nearly the same as with petro diesel, while the specific fuel consumption was higher than that of petro diesel [12]. Carbon deposits inside the engine were normal, with the exception of intake valve deposits. Biodiesel fuels can be performance improving additives in compression ignition engines [13,14]. Performance testing showed that while the power decreased and the brake specific fuel consumption increased for all of the biodiesel samples, compared with diesel fuel, the amount of the changes was in direct proportion to the lower energy content of the biodiesel [15].

3. Case: steps

1. All electrical connections were checked and proper earthing for the equipment's.
2. Water was ensured in the main water supply tank.
3. Selected fuel about 2 litre was ensured in quantity in the fuel supply tank and fuel knob on regular position.
4. Water pump was started. Cooling water flow was checked for engine at 300 LPH and calorimeter flow at 80 LPH. This flow rate was maintained throughout the experiment. Adequate water flow rate was ensured for dynamometer cooling and piezo sensor cooling.

5. Electric-supply to the computer was started through the stabilizer and the engine software was opened.
6. Two power switches provided on the set-up were started and channel selector was set to ‘7’ (load) position. The load was set to minimum position using the rotary knob.
7. Electric power was supplied to the smoke meter and 5-gas analyser.
8. The engine was started by rotating the handle and operating the decompression lever. The engine was run on the minimum load and smoke meter and gas analyzer to get warmed up simultaneously.
9. Fuel properties (calorific value and specific gravity) were changed in the software in the configure option as per the fuel selected for test.
10. Run option was chosen in the software. The engine was run for fifteen minutes so that engine gets stabilized. It was ensured that smoke meter and gas analyzer have reached their default display and then the fuel supply switch was turned to metering position. Log option of the software was chosen. After 1 minute the display changed to input mode then the values of water flow in cooling jacket was entered and calorimeter and then the file name (applicable only for the first reading) in the software. The first reading for the engine gets logged for the no load condition. The fuel knob was turned back to regular position.
11. The handle of the exhaust connection was opened for inserting the gas sample probe of the 5-gas analyzer. The probe was inserted. NO_x mode of the instrument was chosen from the display. After the reading was stabilized the print outs were got by choosing the print option. The fuel name was noted and load value on the print out for future reference.
12. Valve of the smoke meter connection was opened. The back-pressure was adjusted to 75 mm of Hg. By closing the back-pressure valve and the readings for smoke were taken when the value had stabilized. The fuel reference and load value on the print out were noted for future reference.
13. The load was changed to 1 bar BMEP gradually by rotating the loading knob and observing in the monitor for load value. The engine was allowed to run for 10 minutes for stabilization at new load. After stabilization again the fuel knob was turned to metering position and the log option from software was chosen. After one minute after the fuel logging was over, the cooling water was fed and calorimeter flow rates and the fuel knob was turned back to regular position. The readings of 5-gas analyzer and smoke meter were taken as mentioned above.
14. The procedure was repeated for loads of 0, 2, 4 and 6 kg.
15. The load was reduced to minimum position (no load condition) gradually ensuring that the RPM’s were not shooting beyond 1550 RPM and the engine was allowed to stabilize.
16. The files were saved with appropriate names.
17. The engine and computer were put off.
18. The water pumps were allowed to be on for 15 minutes so that engine got cooled down and then the pump was put off.

4. Engine performance: measurement of parameters

The computerised CI engine set up along with a high-speed digital data acquisition system was supplied by ABC India. An eddy current dynamometer, a piezoelectric transducer and digital PT-100 type temperature sensor was calibrated and used in the setup by ABC Innovations. Following parameters were measured from the experimental CI engine setup.

1. Brake power (BP)
2. Brake specific fuel consumption (BSFC)
3. Exhaust gas temperature
5. Cooling water temperature (inlet and outlet)
6. Speed of the engine

Brake power

Brake power is one of the most important parameter in the engine experiment. The SAJ make AG 20 eddy current dynamometer was used for present investigation. The fuel consumption of an engine is measured by determining the time required for consumption of given volume of fuel using a glass burette [16]. The mass of fuel was calculated by multiplying volumetric fuel consumption to its density. An air box with orifice meter and manometer was used for accurate volumetric measurement of air consumption and finally mass flow rate was determined.

Brake mean effective pressure

The BMEP is an important concept for improving different fuels. It is the average pressure the engine can exert on the piston through one complete operating cycle [17]. It is the average pressure of the gas inside the engine cylinder based on neat power. BMEP is important because it is independent of the RPM and the size of the engine.

Brake specific fuel consumption

It defined as the fuel flow rate per unit power output. It is a measure the efficiency of the engine in using the fuel supplied to produce work. It is desirable to obtain a lower value of BSFC meaning that the engine used less fuel to produce the same amount of work [18]. This is one of the most important parameters to compare when testing various fuels.

Brake thermal efficiency

It is the ratio of the thermal power available in the fuel to the power the engine delivers to the crankshaft. This greatly depends on the manner in which the energy is converted since the efficiency is normalized with fuel heating value.

5. Result and discussion

Worldwide, biodiesel is largely produced by methyl transesterification of oils. The recovery of ester as well as its kinematic viscosity is affected by the transesterification process parameters such as catalyst concentration, reaction temperature and reaction time. The above parameters were standardized to obtain methyl ester of waste cotton seed oil with lowest possible kinematic viscosity and highest level of recovery. The engine performance parameters and exhaust gas emission characteristics of B10, B15, B20 and diesel were compared.

Brake Power (BP)

Graph of the brake power (BP) as a function of load obtained during engine operation on different blends of biodiesel i.e. B10, B15 and B20 with diesel (petrodiesel) at compression ratio of 18:1 has been shown in Figure 4.1.

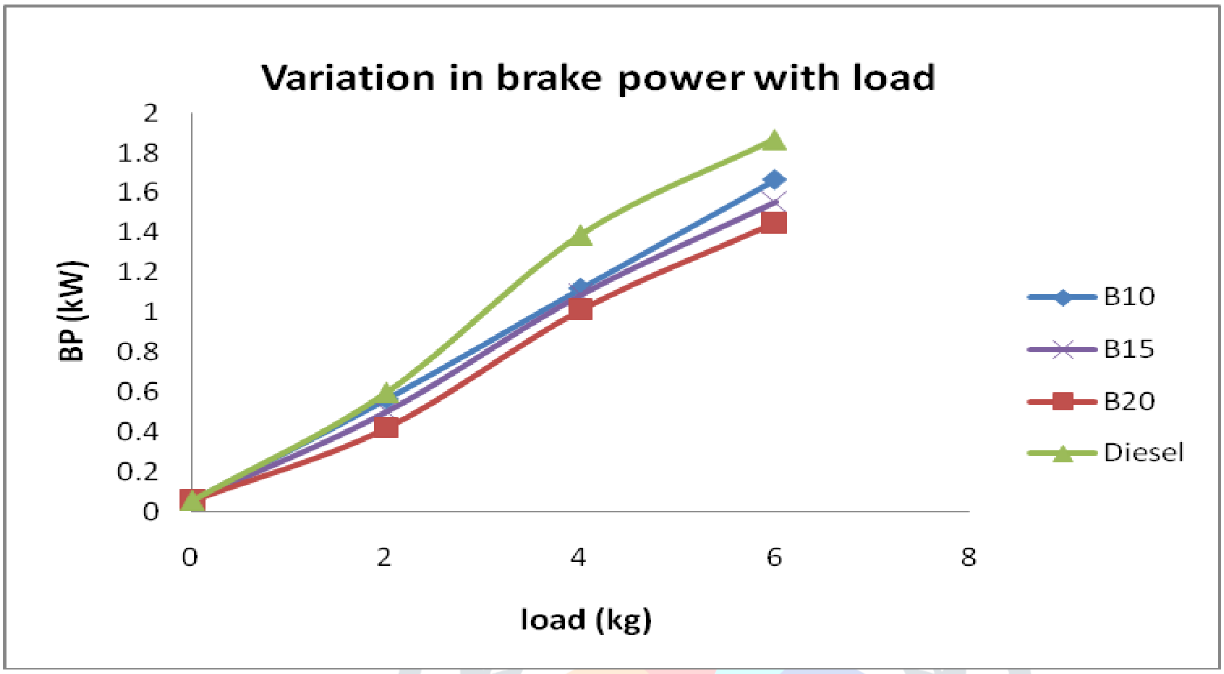

Figure 1: Variation in brake power with change in load

Brake power of the engine increases with increase in the load on the engine. Brake power is the function of calorific value and the torque applied. Diesel has more calorific value than the biodiesel, so diesel has the highest brake power among the different blends of biodiesel. Due to the more calorific value of B10 blend of biodiesel than B15 and B20, it has the more brake power as shown in figure 1. It can also be seen that as we increases the load, torque increases and thus there is an increase in brake power with the load.

Brake specific fuel consumption (BSFC)

Graph of the brake specific fuel consumption (bsfc) as a function of load obtained during engine operation on different blends of biodiesel i.e. B10, B15 and B20 with diesel (petrodiesel) at compression ratio of 18:1 has been shown in Figure 2.

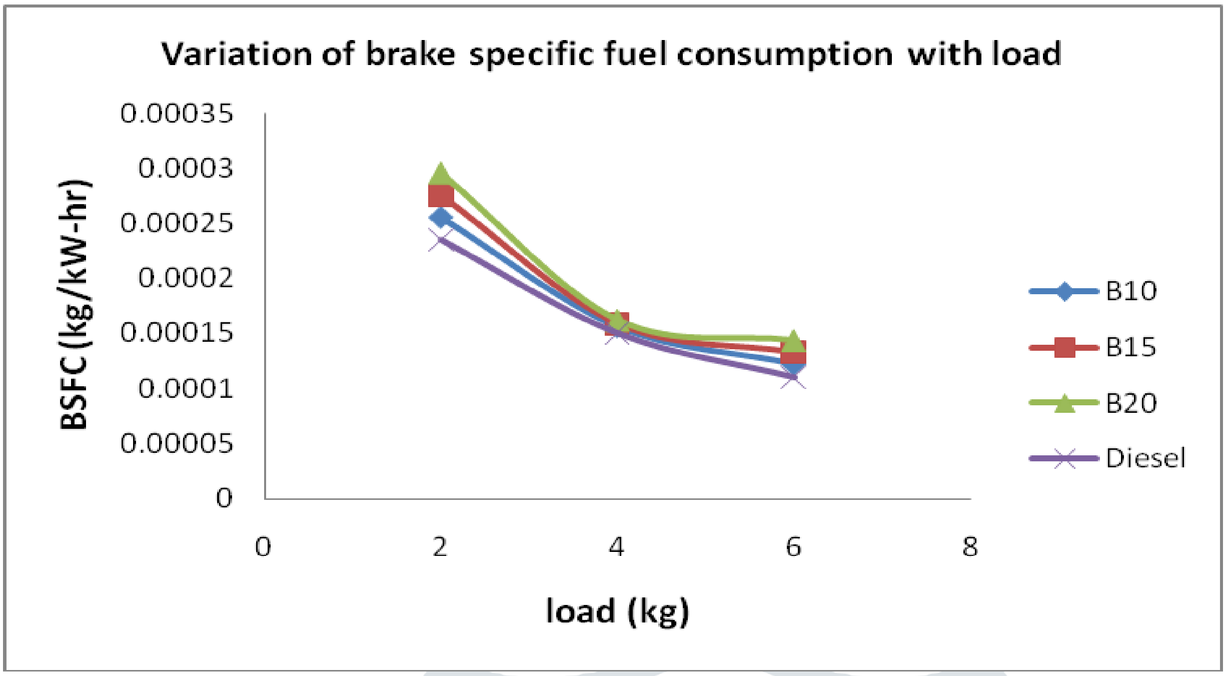

Figure 2: Variation in brake specific fuel consumption with change in load

For all blends and petrodiesel tested, bsfc decreased with increase in load. One possible explanation for this reduction is the higher percentage of increase in brake power with load as compared to fuel consumption. It can be seen from the figure 4.2 that in case of biodiesel mixtures, the BSFC values were determined to be higher than those of neat diesel fuel. This trend was observed owing to the fact that biodiesel mixtures have a lower heating value than does neat diesel fuel, and thus more biodiesel mixtures was required for the maintenance of a constant power output. It is well known that brake specific fuel consumption is inversely proportional to the brake thermal efficiency [19,20]. So diesel has the lowest brake specific fuel consumption. Among the three different blends of biodiesel B10 has the lowest value of brake specific fuel consumption.

Brake thermal efficiency (BTE)

Graph of the brake thermal efficiency as a function of load obtained during engine operation on different blends of biodiesel i.e. B10, B15 and B20 with diesel (petrodiesel) at compression ratio of 18:1 have been shown in Figure 3.

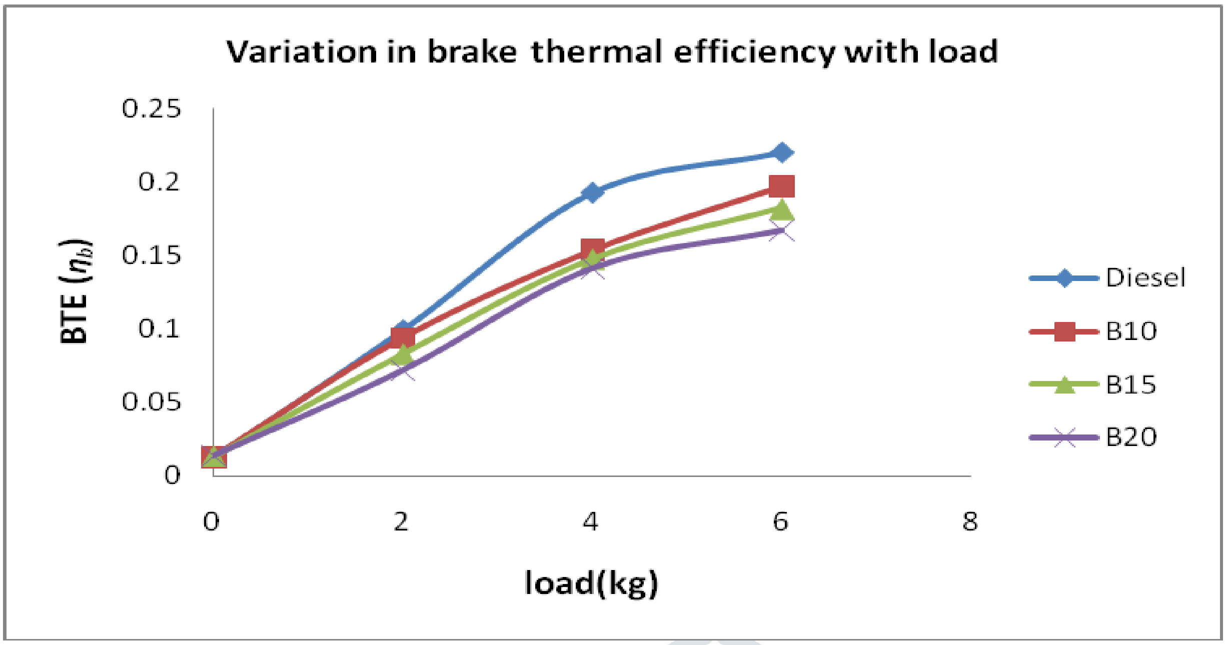

Figure 3: Variation in brake thermal efficiency with change in load

In all cases, brake thermal efficiency increases with an increase in load. This can be attributed to reduction in heat loss and increase in power with increase in load. It is also observed that diesel exhibits slightly higher thermal efficiency at most of the loads than CSOME and its blends. The factors like lower heating values and higher viscosity of the esters may affect the mixture formation process and hence result in slow combustion hence reducing the brake thermal efficiency [21]. The molecules of bio-diesel (i.e. methyl ester of the oil) contain some amount of oxygen, which takes part in the combustion process. Test results indicate that when the mass percent of fuel oxygen exceeds beyond some limit, the oxygen loses its positive influence on the fuel energy conversion efficiency in this particular engine. So the brake thermal efficiency of diesel is more than that of biodiesel blends. Among the three different blends of biodiesel, B10 has higher brake thermal efficiency than B15 and B20.

Exhaust gas temperature (EGT)

Graph of the brake thermal efficiency as a function of load obtained during engine operation on different blends of biodiesel i.e. B10, B15 and B20 with diesel (petrodiesel) at compression ratio of 18:1 have been shown in Figure 4.

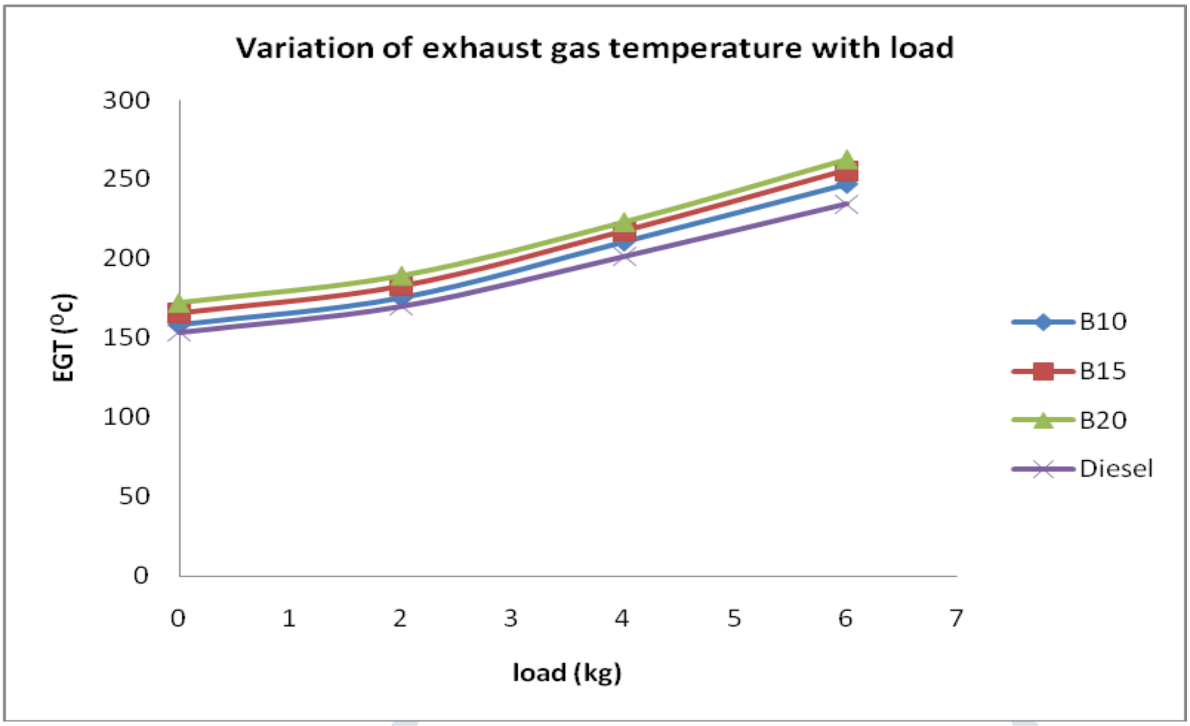

Figure 4: Variation in exhaust gas temperature with change in load

The biodiesel contains some amount of oxygen molecules in the ester form. It is also taking part in combustion. When biodiesel concentration is increased, the exhaust gas temperature increases by small value. Using different blends of biodiesel of cotton seed methyl ester, higher exhaust gas temperature is attained at full load, which is indicating more energy loss in this case. The exhaust gas temperature increases with increase in load. Diesel has the least exhaust gas temperature among the B10, B15, B20 and D. The reason of EGT being more in the case of biodiesel blends is the presence of more oxygen atoms in the biodiesel. So, the exhaust gas temperature increases and it increases with increase in load. As the load on the engine increases, more fuel is burnt. So exhaust gas temperature increases continuously with rise in load.

Conclusions

The overall studies based on the production, fuel characterization, engine performance and exhaust emission of different biodiesel blends of waste cotton seed oil methyl esters were carried out. The recovery of ester by transesterification of waste cotton seed oil with methanol is affected by process parameters such as catalyst concentration and reaction temperature. The kinematic viscosity of diesel, waste cotton seed oil biodiesel was found as 2.049, 3.6 centistokes respectively at 40^0C. The results indicated that the waste cotton seed oil biodiesel had the kinematic viscosity 75.69 percent more than that of diesel. The waste cotton seed oil biodiesel was found to have higher flash and fire point than those of mineral diesel. Waste cotton seed oil biodiesel is non-toxic, biodegradable, environment-friendly, renewable fuels and do not add to global warming. The graphical results show that diesel has better performance characteristics than biodiesel and biodiesel blends. Among the three different blends of biodiesel, B10 has the better performance characteristics than B15 and B20 blend of biodiesel when fuelled in an internal combustion engine.

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