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ORIGINAL

A study of performance and emission characteristics of computerized CI engine with composite biodiesel blends as fuel at various injection pressures

H. Yogish · K. Chandarshekara · M. R. Pramod Kumar

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Abstract Transesterified vegetable oils are becoming increasingly important as alternative fuels for diesel engines due to several advantages. Biodiesel is a renewable, inexhaustible and green fuel. This paper presents the various properties of the oils derived from Jatropha and Pongamia, their mixes and biodiesels derived from the mixes. An innovative lab scale reactor was designed and developed for biodiesel production from mixed vegetable oils and used for the study of optimization of biodiesel yield [1]. Also, the analysis of data of experimental investigations carried out on a 3.75 kW computerized CI engine at injection pressures of 160 and 180 bar with methyl esters of mixed Jatropha and Pongamia in various proportions are also presented. The brake thermal efficiency for biodiesel blends was found to be higher than that of petrodiesel at various loading conditions. In case of Composite biodiesel blended fuels, the exhaust gas temperature increased with increase in load and the amount of composite biodiesel. The highest exhaust gas temperature was observed as 213 °C for biodiesel among the five loading conditions. When petrodiesel was used the exhaust gas temperature was observed to be 220 °C. The CO_2, CO, HC and NO_x emissions from the biodiesel blends were lower than that of petrodiesel.

H. Yogish (✉) · K. Chandarshekara · M. R. Pramod Kumar
Department of Mechanical Engineering, S.J. College
of Engineering, Mysore 570006, India
e-mail: h_yog@hotmail.com

K. Chandarshekara
e-mail: dr.chandrusjce@gmail.com

M. R. Pramod Kumar
e-mail: 999.pramod@gmail.com

1 Introduction

India is the home for over a billion people, which is about one-sixth of the world's population. The population is continuing to grow at 1.93 % per annum, which is well above the global average. The population of India has nearly tripled in the last 50 years, from 361 million in 1951 to an estimated value of 1.22 billion in 2012. The country's economy has also been growing rapidly in the last decade, with gross domestic product growth rate remaining consistently over 5 %. The petroleum products play an important role in our modern life [2–4]. In India, Petrodiesel is a crucial fuel to drive many sectors such as transportation, agriculture, power generation and industry. Among many other oil importing countries, India has spent a majority of its revenue on the import bill of petroleum products. It is even greater than the total of main agricultural products' export [5, 6]. Ever since the invention of Internal Combustion engine (IC), in particular Compression Ignition engine (CI), many improvements have taken place in engine design. Since Petroleum reserves are not being spread over the entire world evenly, the oil-rich countries are virtually ruling the world in the supply of fossil fuels [7]. The scarcity of conventional fossil fuels, growing emissions of combustion-generated pollutants [8] and their increasing costs are making sources of alternative fuels more attractive [6]. Therefore, biodiesel and ethanol are being considered to be supplementary fuels to the petrodiesel in the country. In addition to that, these biofuels are being looked at to provide employment to rural mass through plantation of non-edible oil yielding sources such as Jatropha, Pongamia, Madhuca Indica etc. [9]. The plantation of non-edible oil yielding sources on waste land could also eliminate the food crisis which would result from using edible oils for production of alternative fuels.

The concept of using biofuels in diesel engines originated from the demonstration of first diesel engine by the inventor "Rudolf Diesel" at the World Exhibition at Paris in 1900 by using peanut oil as fuel. However, due to copious supply of petrodiesel, Research and Development activities, both on edible as well as non-edible vegetable oils were not critically pursued. It received much attention only recently when it was realized that petroleum fuel resources are dwindling fast and environment-friendly renewable substitutes must be identified. In the recent years, serious efforts have been made by several researchers to use different source of energy as fuel in existing diesel engines. The use of straight vegetable oils is restricted by some unfavorable properties of them, particularly their viscosity [10].

Fuels derived from renewable biological resources for use in diesel engines are known as biodiesel. Biodiesel is environment friendly liquid fuel similar to petrodiesel in properties and combustion characteristics. Increasing environmental concern, diminishing petroleum reserves and agriculture based economy of the country are the driving forces to promote biodiesel as an alternate fuel. Biodiesel derived from vegetable oil and animal fats are being used in USA and Europe to reduce air pollution and to reduce dependence on fossil fuels. In USA and Europe, their surplus edible oils like soybean oil, sunflower oil, rapeseed oils, algae, and chicken fat are being used as feed stock for the production of biodiesel [11]. But these feed stocks cannot be used for production of biodiesels in underdeveloped and developing countries as they would cause food crisis.

In this present work, the oils of Jatropha and Pongamia are mixed in various proportions like M1: %90J + %10P, M2: %80J + %20P, M3: %30J + %70P, M4: %40J + %60P, M5: %50J + %50P. The properties of mixed oil of Jatropha and Pongamia, Jatropha oil and Pongamia oil such as Flashpoint, Fire point, Viscosity, Calorific Value, Density and pH value were investigated and tabulated in Table 1. These mixes are converted into biodiesel by two step transesterification process in an innovative laboratory scale biodiesel reactor as shown in Fig. 1. The optimum combinations were identified which gave the maximum yield for mixed oils (about 95 %). Also, the properties such as Flash Point, Fire point, Density, Specific gravity, Viscosity, Calorific Value, Iodine Value, Acid value, Sulfur content, Water content, Glycerin content, Sulfated Ash, pH Value, Cloud point and Pour point were determined and are tabulated in Table 2. It was found that these properties are in compliance with BIS standards and comparable with the properties of petrodiesel [1]. Five blends were obtained with mixing diesel and composite biodiesel in the proportions B10, B20, B30, B40 and B50 and used as fuel in the engine. The performance parameters like Brake power, Brake Thermal Efficiency, Specific Fuel Consumption were determined. Exhaust emission like CO$_2$, CO, NO$_x$ and HC have been evaluated. These values are tabulated in Tables 3 and 4.

Table 1 Properties of mixed oil in various proportions of Jatropha and Pongamia

Oil ratio	Calorific value (MJ/kg)	Density (kg/m^3)	Flash point (°C)	Fire point (°C)	Viscosity (cSt.)	pH value
M1	39.75	901	268	278	48	6.68
M2	39.60	903	264	275	52	6.55
M3	39.43	907	262	270	61	6.45
M4	39.26	911	257	268	71	5.24
M5	39.09	916	252	265	80	4.96
Jatropha	37.0	860	210	250	50	5.90
Pongamia	36.0	920	230	265	60	6.00

Fig. 1 Laboratory scale biodiesel reactor

2 Materials and methodology

Non edible Jatropha and Pongamia oils were selected owing to their suitability as feedstock for biodiesel production. These oils were supplied by Bannari sugar mills limited, Coimbatore, India. They were mixed in suitable

Table 2 Properties of composite biodiesel

Sl. No.	Properties	Petrodiesel	Methyl ester of Jatropha	Methyl ester of Pongamia	Methyl esters of composite biodiesel					BIS standard for biodiesel fuel
					ME-M1	ME-M2	ME-M3	ME-M4	ME-M5	
1	Specific gravity	0.822	0.860	0.880	0.828	0.832	0.839	0.851	0.870	0.86–0.90
2	Density (kg/m^3)	822	860	880	828	832	839	851	870	860–900
3	Viscosity (cSt at 40 °C)	2.00	3.50	4.00	2.55	2.85	2.90	3.38	4.22	2.5–6.0
4	Flash point (°C)	68	130	140	121	125	130	135	158	120
5	Fire point (°C)	80	150	160	140	155	165	172	172	Not mentioned
6	Calorific value (MJ/kg)	48.90	42	40	45.51	46.62	47.73	46.62	46.62	Not mentioned
7	Iodine value (mg/g)	–	104	112.5	60	75	90	94	100	120 (max)
8	Acid value (mg/KOH/g)	–	0.40	0.42	0.48	0.43	0.38	0.29	0.43	0.5
9	Sulfur content (mg/kg)	500 (max)	38	43	41	47	40	29	47	50 (max)
10	Water content (mg/kg)	200 (max)	435	458	428	493	431	381	470	500 (max)
11	Glycerin content (%)	–	0.167	0.183	0.210	0.213	0.203	0.0018	0.0013	0.25
12	Sulfated ash (%)	0.05 (max)	0.0011	0.0015	0.0012	0.003	0.001	0.002	0.0018	0.02 (max)
13	pH value	7.1	7.2	6.85	6.96	6.95	6.92	6.96	6.91	≥7
14	Cloud point (°C)	2	10	13	5	6	10	6	12	–
15	Pour point (°C)	−5	2	3	−1	0	1	−1	3	–

Table 3 Extracted maximum values and minimum values of performance and emission parameters respectively out of 150 trials at injection pressure of 180 bar

Fuels used	Performance parameters					Emission parameters			
	FC (kg/h)	BP (kW)	BTE (%)	RoHR (J/ca)	BSFC (kg/kW-h)	CO_2 (%)	CO (%)	NO_x (°C)	HC (ppm)
Petro-diesel	0.6	2.57	36.3	64.68	0.23	4.8	0.07	202	121
M1B30	0.54	2.52	35.6	53.74	0.24	3.8	0.04	183	101
M2B40	0.54	2.56	40.2	59.12	0.21	3.1	0.04	173	103
M3B20	0.48	2.54	44.8	53.12	0.19	3.1	0.06	173	102
M4B20	0.48	2.55	45	52.57	0.19	2.7	0.04	160	100
M5B50	0.54	2.53	39.7	60.09	0.21	3.2	0.06	182	102

proportions and the mixes were coded as M1, M2, M3, M4 and M5. There were no separate layers formed in the mixes due to the fact that both oils had similar mass densities [1]. These mixes were subjected to a two step acid and base transesterification process depending on Free Fatty Acid (FFA) content which was ascertained by the FFA test.

The mixes were transformed into composite biodiesel in an innovatively designed lab scale reactor (Fig. 1) to reduce the process time and optimize the process parameters. After several trials, it was observed that 90 min of reaction time, 60 °C of reaction temperature, 262.50 g of Methanol, 11.25 g of Sodium hydroxide (NaOH) and 22.50 g of Sulphuric acid (H_2SO_4) were the optimum quantities to get the biodiesel yield of 95 %. The Biodiesels thus obtained from the various mixes were tested for various properties [1]. The engine testing setup consisted of unmodified computerized diesel engine coupled with Direct Current (DC) alternator, and loading was done using an electrical load as shown in Figs. 2 and 4, the specifications are given in Table 5. For determining exhaust gas constituents an ECO GAS-4 analyzer was used (Figs. 3, 4) and its specifications are given in Table 6. The flow rate of engine coolant was measured using a Rotameter. Fuel flow rate, air flow rate, torque, speed and various temperatures were measured using digital indicators present on the test rig.

2.1 Experimental program and procedure

The five blends were used as the fuel for all the trials conducted on the engine. The engine speed was kept constant at 1,500 rpm for all the trials.

The exhaust gas analyzer was used to measure the various emission parameters such as CO_2, O_2, HC and CO. The ambient and exhaust gas temperatures were also recorded by using the same the equipment.

Table 4 Extracted maximum values and minimum values of performance and emission parameters respectively out of 150 trials at injection pressure of 160 bar

Fuels used	Performance parameters					Emission parameters			
	FC (kg/h)	BP (kW)	BTE (%)	RoHR (J/ca)	BSFC (kg/kW-h)	CO_2 (%)	CO (%)	NO_x (°C)	HC (ppm)
Petro-diesel	0.6	2.41	34	64.68	0.25	5	0.1	220	120
M1B20	0.6	2.41	34	61.04	0.25	4.6	0.1	213	110
M2B30	0.6	2.46	34.7	62.56	0.24	4.4	0.09	210	117
M3B30	0.6	2.47	34.9	63.59	0.24	4.3	0.05	191	106
M4B20	0.6	2.46	34.7	62.27	0.24	4.4	0.08	210	116
M5B20	0.6	2.41	34.2	62.27	0.25	4.6	0.06	210	112

Experiments were initially carried out on the engine using petrodiesel as the fuel in order to provide the base data [12–14]. Then the composite biodiesel blends B-10, B-20, B-30, B-40 and B-50 were used as the engine fuel. The primary objective of the study was to establish usefulness and adaptability of non-edible oils in the mixed form for various sectors utilizing biodiesel as the fuel without modifications of the engine in use. The modification may be very minimal with respect to the change in injectors to suit the use of biodiesel mix.

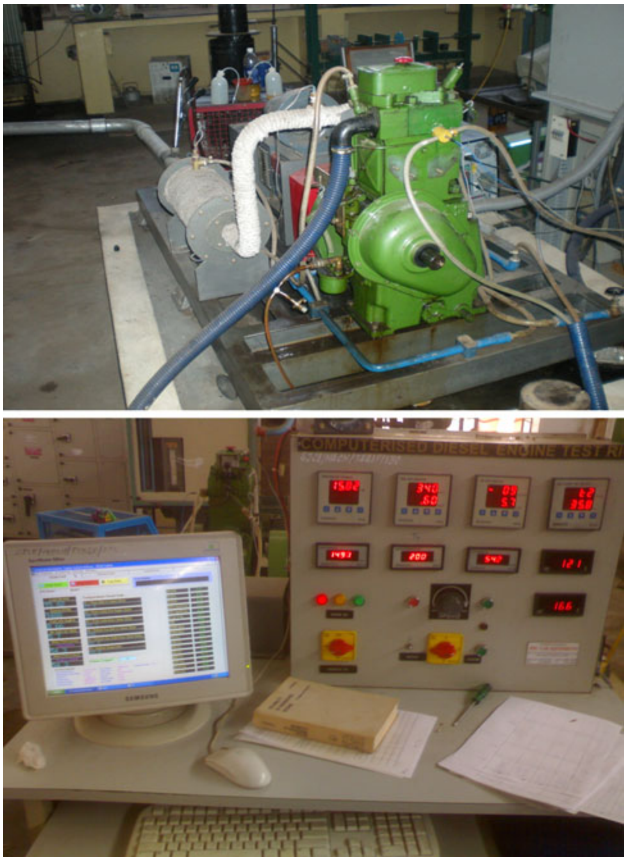


Fig. 2 Computerized CI engine with computer and Display unit

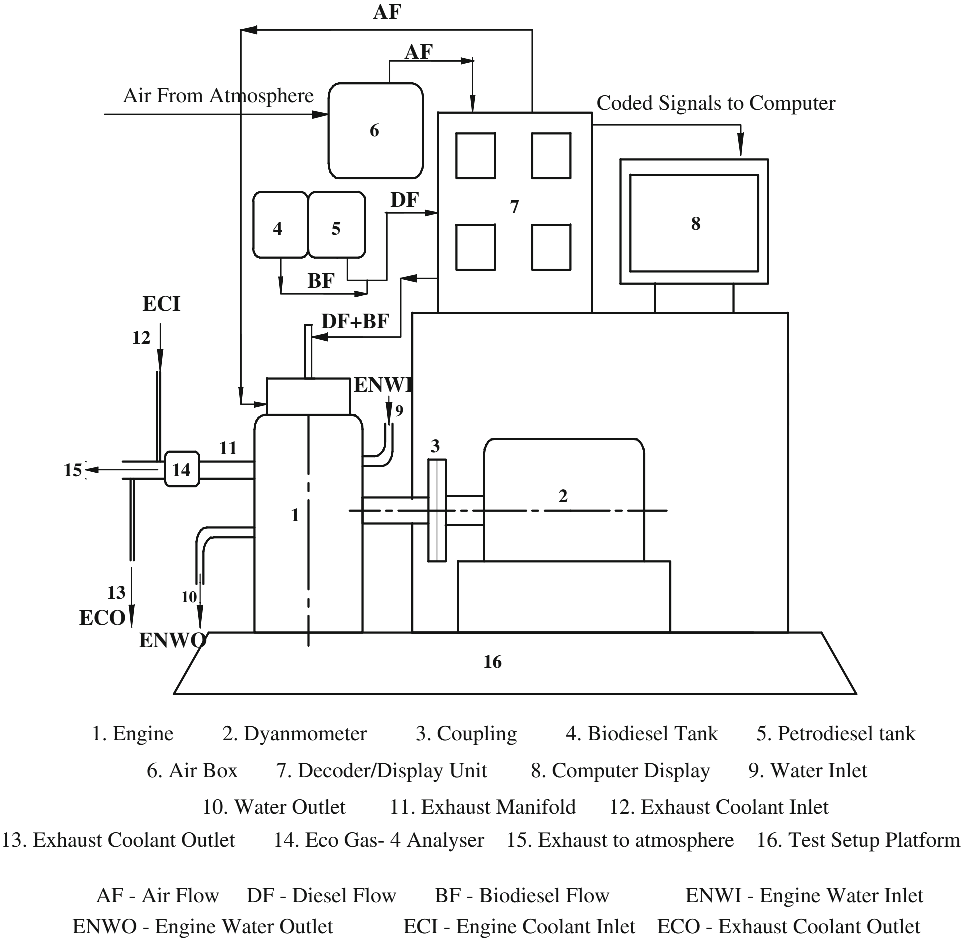
The Injection timing used for all the trials was 25° bTDC. The injection timing was kept constant for all the trials for the chosen injection pressure [15]. The Injection Quantity varied between 0.12 and 0.16 mg/cycle depending on minimum to maximum load and injection pressures. The injection duration was 2.78 µs. A digital fuel indicator

Table 5 Technical specification of diesel engine

Manufacturer	Kirloskar engines Ltd, Pune
Number of cylinders	One
Number of strokes	Four
Bore and stroke	80 and 110 mm
Capacity	3.75 kW
Compression ratio	1:17.5
Rated speed	1,500 rpm
Mode of injection	Direct injection
Cooling system	Water cooling
Designed injection pressure	180 bar
Injector type	Multi hole (3 holes), with 20° inclination of holes and 0.20 mm diameter of holes
Dynamometer	Eddy current dynamometer with a loading unit

Fig. 3 ECO GAS-4 exhaust gas analyzer

Fig. 4 Schematic diagram of test rig



with strain gauge type differential transducer with reset facility was provided with its output connected to an indicator of a Data Acquisition System and then to the computer.

The cooling water temperature at the outlet was maintained at 60 °C. The temperature of the product of combustion after constant pressure heat addition process was observed to be in the range of 600–750 °C after certain amount of heat energy is carried away by the Cooling water over the range of the loads. This temperature range was ensured by maintaining the coolant temperature at 60 °C by properly adjusting the flow rate which varied between 0.3 and 0.48 kg/min of the engine coolant. The engine was allowed to reach steady state conditions before taking all the measurements. Subsequently experiments were repeated with Methyl Ester of composite oil.

The experiments were conducted at Injection pressures of 160 and 180 bar for all the mixes and blends of biodiesel. Totally 300 trials were conducted on all the mixes and blends. Additional trials were also conducted to ascertain the repeatability of the results at the above said pressures.

3 Results and discussion

About 150 trials were conducted for all the mixes and blends for injection pressures of 160 bar. Similar number of trials was conducted at 180 bar. In the figures, for each of the parameters, the maximum values and minimum values are considered for depicting and comparing the performance and emission parameters of the composite biodiesel with petro diesel at the considered pressures. Maximum performance parameters and minimum emission parameters at 180 and 160 bar injection pressures are termed as 180 Diesel and 160 Diesel and for biodiesel mix and blends are termed as 180M4B20 and 160M3B30 in the figures. The maximum values for performance at 180 bar for diesel are termed as 180diesel and for biodiesel as 180M4B20. Similarly, 160diesel and 160M4B20 mean maximum values of performance of diesel and biodiesel respectively. With respect to these representations in Figs. 5, 6, 7, 8, 9, 10 and 11, the minimum values of emissions of petrodiesel and biodiesel are represented. Also, Figs. 12, 13, 14, 15, 16, 17, 18, 19 and 20 depict unified graphs for performance and emission parameters. Since, for different parameters, different ranges are there,

Table 6 Technical specification of ECO GAS-4

Technical specifications			
Measurement parameters	Range	Resolution	Accuracy
	0–9.99 %	0.01 %	±0.03 % absolute or ±3 % relative whichever is higher
CO_2	0–19.9 %	0.10 %	±0.4 % Absolute or ±4 % relative whichever is higher
HC	0–15,000 ppm	1 ppm	±10 ppm absolute or ±5 % relative whichever is higher
O_2	0–25 %	0.01 %	±1 % absolute or ±3 % relative whichever is higher
NO_x	0–5,000 ppm	1 ppm	±20 ppm absolute or ±4 % relative whichever is higher
Air fuel ratio	0–30 %	0.01 %	
Engine speed	400–9990 rpm	10 rpm	

to have a common range, Division Factors (DFs) are used. For example, for performance parameters like BP and BTE, DFs of 10 and 100 respectively are used. Obviously, to obtain the values of these parameters, on the Y-axis, the Y-ordinate cutting line from a point on these curves must be multiplied by the corresponding DFs. Similarly, for emission parameters, like CO_2, DF 10 is used, for HC and NO_x DFs 1000 is used.

3.1 Fuel consumption

The fuel consumption increased with increase in amount of biodiesel in the blends as shown in Fig. 5. In case of composite biodiesel blends, the fuel consumption was about 20 % lower than that of petrodiesel for 180M4B20. The values are 0.48 kg/h for M4B20 blend and 0.6 kg/h for petro diesel at 180 bar and it is 0.6 kg/h for the composite biodiesel and petrodiesel at an injection pressure of 160 bar at full load. The Specific gravity and viscosity of 180M4B20 at room temperature (30 °C) by measurement and calculation by weighted average method was found to be 0.8452 and 3.104cST. At the same temperature petrodiesel's specific gravity and viscosity were 0.822 and 2.00cST respectively. When the fuel with the higher specific gravity (or high bulk modulus) and lower viscosity is

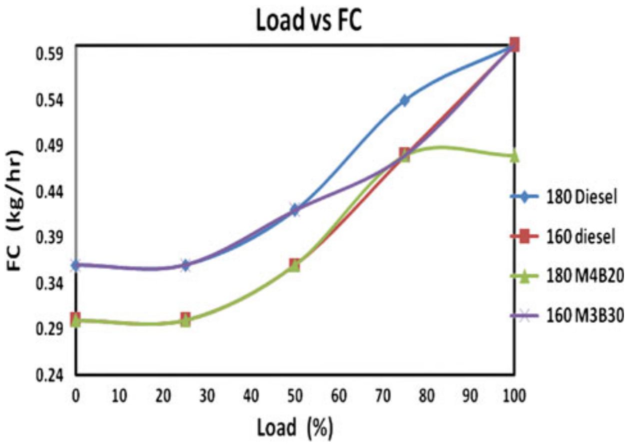


Fig. 5 Variations of fuel consumption with load

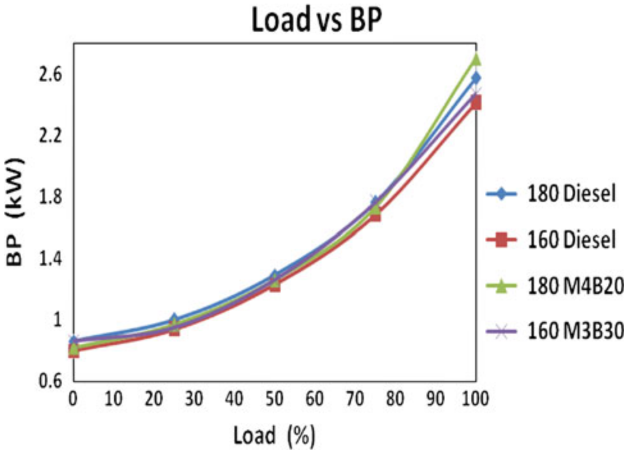


Fig. 6 Variations of brake power with load

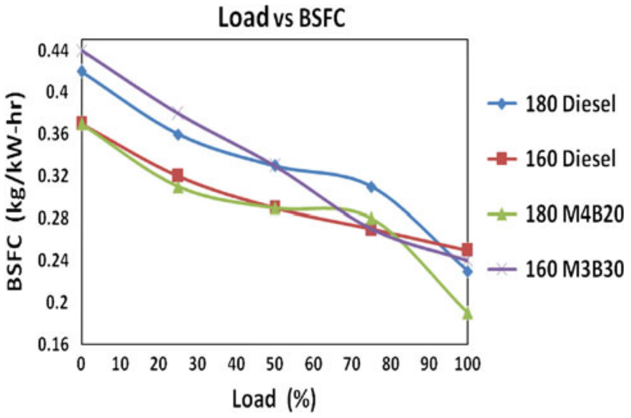


Fig. 7 Variations of specific fuel consumption with load

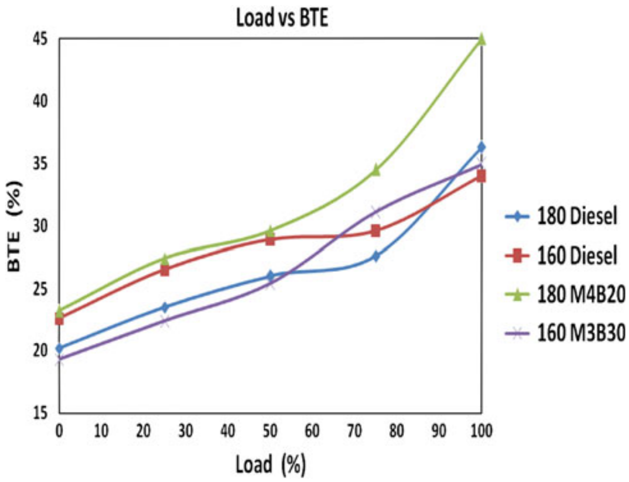


Fig. 8 Variations of brake thermal efficiency with load

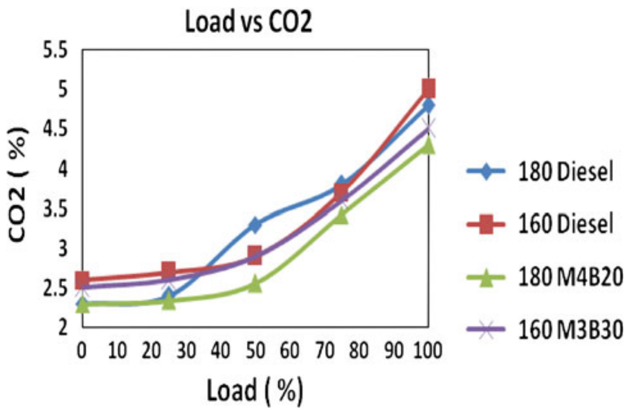


Fig. 9 Variations of CO_2 with Load

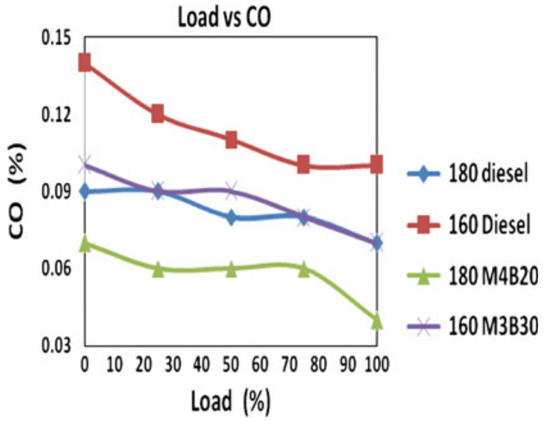


Fig. 10 Variations of CO with load

injected, the pressure wave travels faster from pump end to nozzle end, through an in-line fuel discharge tube. This causes early lift of needle in the nozzle, causing advanced injection. It is also observed that the fuel consumption decreases and the reason is attributed to the improved combustion caused by increased evaporation and spray characteristics as percentage of biodiesel increases in the blend.

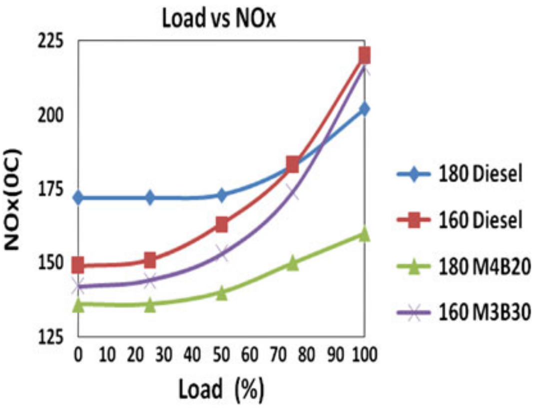


Fig. 11 Variations of NO_x with load

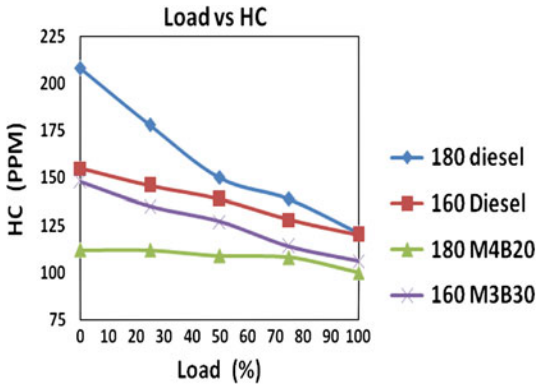


Fig. 12 Variations of hydrocarbon with load

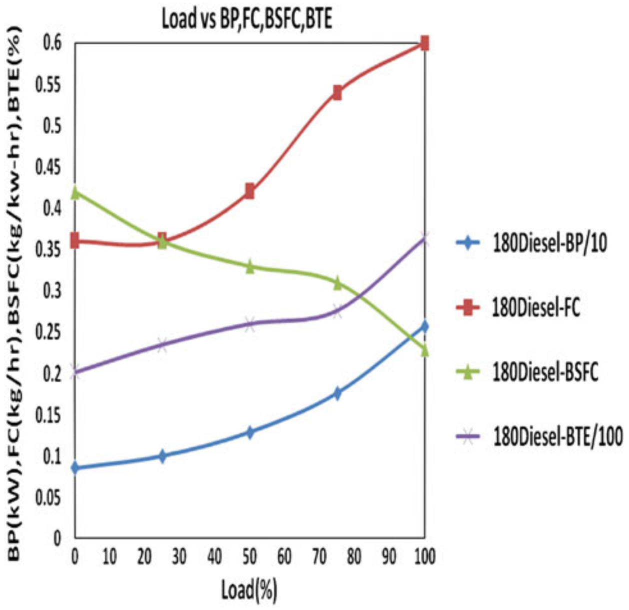


Fig. 13 Variations of BP, FC, BSFC, BTE with load

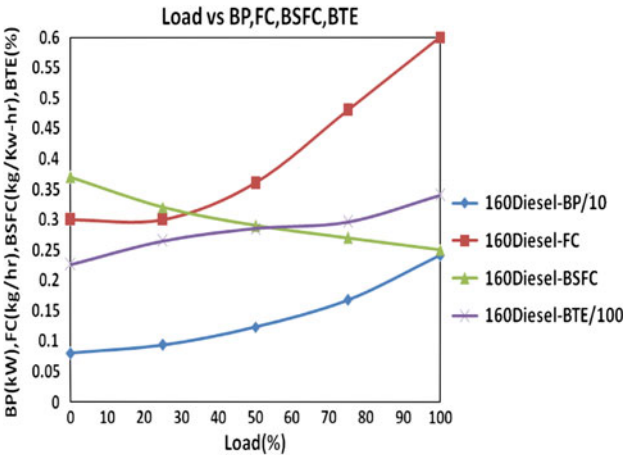


Fig. 14 Variations of BP, FC, BSFC, BTE with load

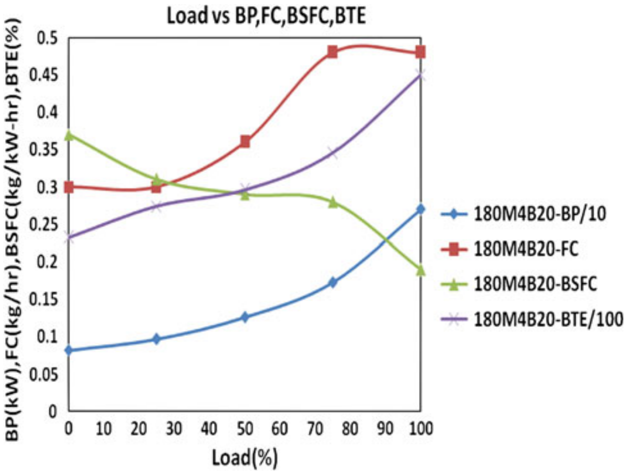


Fig. 15 Variations of BP, FC, BSFC, BTE with load

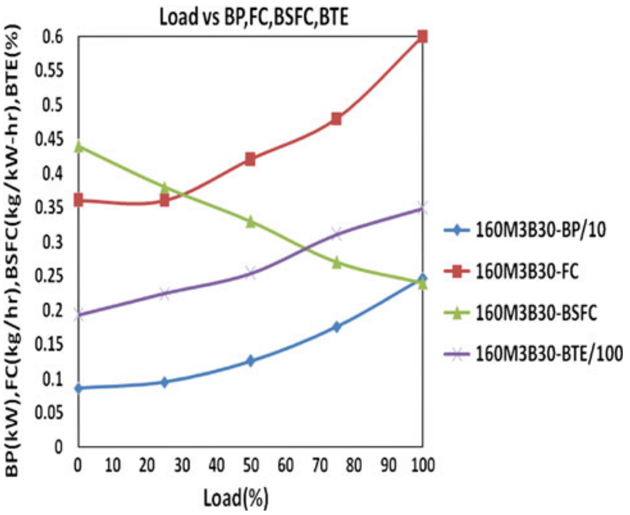


Fig. 16 Variations of BP, FC, BSFC, BTE with load

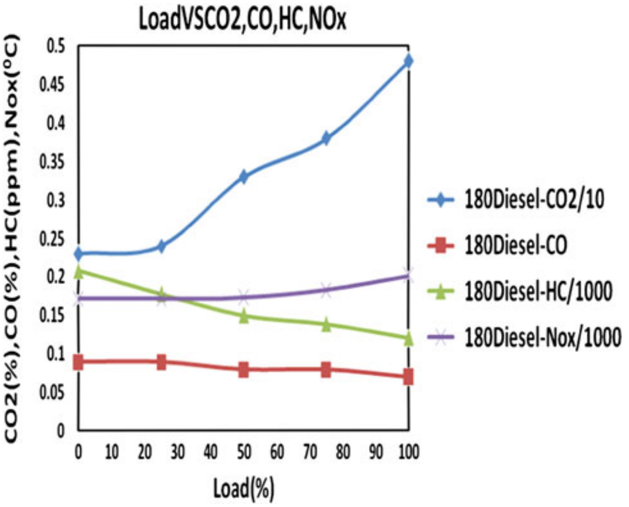


Fig. 17 Variations of CO_2, CO, HC, NO-x with load

3.2 Brake power

Figure 6 shows the variation of brake power with increasing load on the engine. It can be seen that the biodiesel blend 180M4B20 yielded the maximum value for the brake power at full load. The brake power of petrodiesel was obtained as 2.57 kW at 180 bar and 2.41 kW at 160 bar injection pressures. Among all the biodiesel blends, the brake power of M4B20 was 2.7 kW at 180 bar and is maximum in comparison with petrodiesel. It is true that the specific gravity of most methyl esters is higher than that of petrodiesel. With increase in percentage of biodiesel in blends the specific gravity of mixes increase [16]. This is due to larger molecular mass and chemical structure of vegetable oils. The specific gravity is depended on molecular weight, FFA content, water content and temperature. Higher specific gravity increases cetane number which provides greater torque. It has been observed that, the composite biodiesel mix (COME) is burning close to top dead center (TDC) and the peak pressure is higher than that of petrodiesel. The reason is attributed to the higher bulk modulus of the COME. Obviously, the combustion is taking place nearer to TDC and the peak pressure is high due to existence of smaller cylinder volume near TDC. Therefore the reason for peak pressure is attributed to the combined effect of advanced injection and lower value of heat rejection, which occurs due to prevalence of smaller cylinder volume near TDC. This relates to lower fuel consumption and higher power for the considered mix and blend [17, 18].

3.3 Specific fuel consumption (BSFC)

The results for the variation in the BSFC with increasing load on the engine for the various fuels are presented in Fig. 7. For all fuels, the specific fuel consumption falls with increasing load (increasing torque on the engine). The

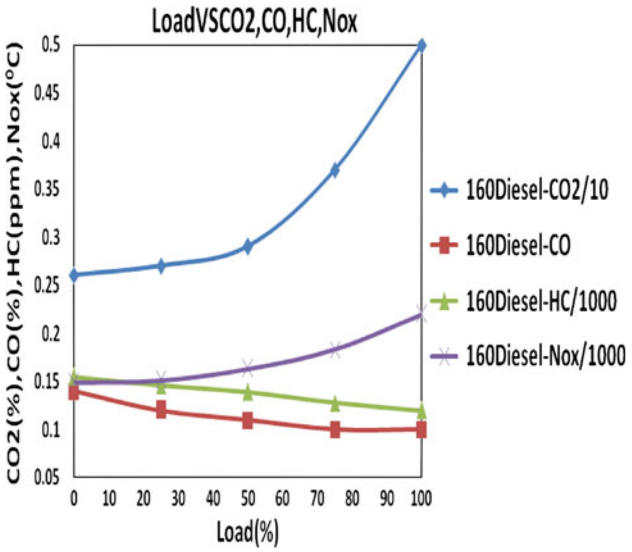


Fig. 18 Variations of CO_2, CO, HC, NO-x with load

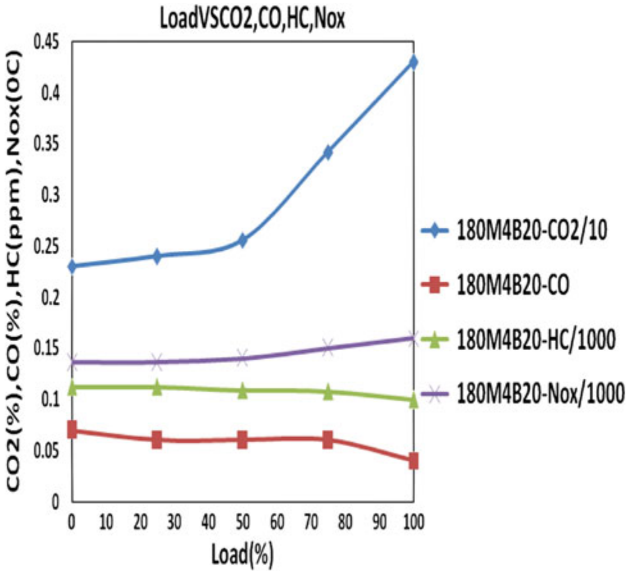


Fig. 19 Variations of CO_2, CO, HC, NO-x with load

specific fuel consumption of petrodiesel was obtained as 0.23 kg/kW-h at 180 bar and 0.25 kg/kW-h at 160 bar injection pressures. It can be observed that, the BSFC of biodiesel blend M4B20 at 180 bar (0.19 kg/kW-h) at full load is minimum compared to petrodiesel and all other blends. The main reason for low BSFC and higher power generation is that, the constituents of the fuel blend with higher oxygen content are adequate to ensure superior and complete combustion of the fuel during the first phase of combustion due to factors considered in Sect. 3.2. Also, higher cetane number associated with higher specific gravity, which results in higher RoHR and higher availability (energy available at higher temperature) and superior combustion at peak pressure, lower heat rejection are the reasons for lower BSFC and higher power generation. One must also note that the calorific value of 180M4B20 is not significantly lower than that of petrodiesel but is comparable to other blends and mixes [19, 20].

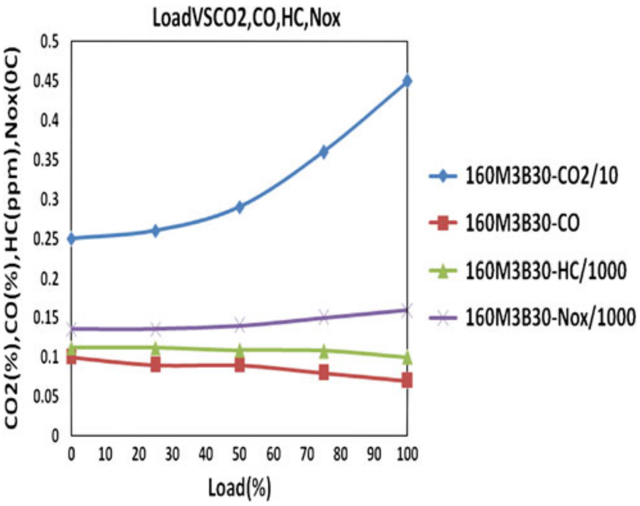


Fig. 20 Variations of CO_2, CO, HC, and NO-x with load

3.4 Brake thermal efficiency (BTE)

Figure 8 depicts the variation of BTE with load. BTE is the highest for M4B20 blend at full load (45 %) and at injection pressure of 180 bar and 36.4 % for 160M3B30. For the petrodiesel at the full load, the value is 36.3 % at injection pressure of 180 bar. 180M4B20 composite oil methyl ester (COME) shows the maximum efficiency. The higher efficiency is due to high volatility, slightly lower viscosity, higher oxygen content, higher RoHR, higher injection pressure and higher availability of the ethyl ester of the composite oil and higher peak pressure which facilitates the better mixture formation of the fuel and thus leading to superior and complete combustion nearer to TDC, due to synergetic effect of the above said parameters of COME in the mix [18, 21].

3.5 Carbon dioxide (CO_2)

The carbon dioxide emission from the petrodiesel engine with different blends is shown in Fig. 9. The CO_2 increased with increase in load conditions for petrodiesel and also for biodiesel blended fuels. The blend M4B20 emitted 4.3 % of CO_2 and petrodiesel emitted 4.7 % of the same at 180 bar injection pressure. It is lowered by 8.5 % compared to petrodiesel. This is due to the fact that biodiesel in general is a low carbon fuel and has a lower elemental carbon to hydrogen ratio than petrodiesel.

3.6 Carbon monoxide (CO)

The variation of CO emissions from the petrodiesel with biodiesel blends is shown in Fig. 10. With biodiesel M4B20, the lowest CO was 0.04 % at full load and that of petrodiesel was 0.07 % at 180 bar injection pressure. Similar results were obtained for biodiesel blends. The amount of CO emission was lower in case of biodiesel blends than petrodiesel because of the fact that biodiesel contains more oxygen molecules. This leads to superior combustion and hence reduction in CO emission.

3.7 Nitrogen oxide (NO_x)

The NO_x emissions from the engine with different composite biodiesel blends and biodiesel are shown in Fig. 11. The NO_x emission for biodiesel blends increased with increase in load. The exhaust temperature was the lowest for M4B20 (160 °C) when compared to petrodiesel (202 °C) at an injection pressure of 180 bar. The lowest temperature for M4B20 was 210 °C when compared to petro diesel which was 220 °C at 160 bar injection pressure. NO_x emissions of biodiesel blends were lower than petrodiesel at full load. The ignition timing, ignition duration were also kept constant, injection quantity varied depending on the load. It has also been observed that, water cooling flattens the engine temperature meaning that the temperature of the engine does not increase if the flow rate and the temperature are maintained at the required quantities. The NO_x emission is a direct function of engine loading and exhaust temperature. The NO_x values predicted here are only based on the exhaust temperature. From the Tables 3 and 4 it could be observed that for petro diesel the RoHR is maximum for both the injection pressures of 180 and 160 bar. The blend 180M4B20 has maximum percentage of biodiesel 80 % for which RoHR is 52.57 J/ca which is minimum compared to all other biodiesel blends. The combustion rate, as indicated by the RoHR, also has an effect on NO_x production. Higher premixed combustion means a higher initial rate of combustion which results in increase in NO_x. Premixed fuel means that fuel is mixed with air and prepared to burn during the ID period. Premixed combustion means combustion during ID period. When this fuel auto ignites it usually burns very quickly. CN and fuel volatility are the two most important properties that determine the combustion rate. High CN and low volatility lowers the combustion rate. A biodiesel with a high CN is expected to shorten the ID period and thus lower the amount of fuel that is involved with the premixed portion of the biodiesel combustion, thus lowering NO_x emission. Reasons mentioned in other sections and based on the values of RoHR, the NO_x values reduced with respect to increase in biodiesel and optimum minimum value was observed for the mix M4B20 at 180 bar injection pressure compared to petrodiesel and other blends.

3.8 Hydro carbon emission (HC)

The variations of HC emissions from petrodiesel and petrodiesel—biodiesel blends are shown in Fig. 12. With biodiesel M4B20, the lowest HC was 100 ppm at full load and that of petrodiesel was 121 ppm at 180 bar injection pressure. At 160 bar injection pressure, it was observed to be 116 ppm for M4B20 and 120 ppm for petrodiesel. Similar results were obtained for biodiesel blends and composite biodiesel with lower emission than petrodiesel for other biodiesel blends. The amount of HC emission was lower in case of biodiesel blends than petrodiesel by 17.35 % because of the fact that during transesterification process the triglycerides molecular structure of composite oil is converted into mono-alkyl esters molecular structure of biodiesel. Also, the oxygen content in the biodiesel blends is more than petrodiesel. These factors make breaking of molecules easier and hence the combustion process is superior and complete. This reduces the cracking reactions of the high molecular weight fractions, thus reducing the emission. Obviously, there is reduction in HC emissions in biodiesel blends compared to petrol diesel at both the pressures when used as fuels in the engine.

4 Conclusion

A computerized CI engine with alternator was used to conduct performance and emission tests with composite biodiesel blends and petrodiesel and the results are compared. A lab scale reactor was designed and developed for reduction and optimization of reaction time and used for biodiesel production from composite oil. The properties of composite biodiesel were found to be similar to the petrodiesel. About 300 trials were conducted on petrodiesel and five mixes of ethyl ester, and five blends for each mix of ethyl ester. In the case of composite biodiesel, the fuel consumption was 20 % lower than that of petrodiesel. The percent decrease in specific fuel consumption was 18 % compared to petrodiesel. The brake thermal efficiency for biodiesel and its blends was found to be 34 % higher than that of petrodiesel. Reductions in major exhaust pollutants were: CO—42.8 %, HC—17.35 %, NO_x—19.01 % and CO_2—8.5 % in comparison with the petrodiesel. Hence, it could be concluded that the composite biodiesel could be a substitute for fossil fuel in the coming years.

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