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Research Articles

Study on use of biodiesel ethanol blend as a substitute in diesel engine

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ABSTRACT

Alcohol in diesel engines can be used by two methods, one through fumigating alcohol in the combustion chamber using a carburetor and second is using alcohol and biodiesel blends. Blending of ethanol with biodiesel is easier. However, blending of ethanol is limited by proof level of ethanol; phase separation of ethanol-biodiesel blend occurs. This problem of phase separation should be solved by using certain surfactant like 1-butanol ethyl acetate etc. The substitute fuel of anhydrous and aqueous ethanol with biodiesel was prepared using ethyl acetate as surfactant and their stability at room temperature was observed.A Compression Ignition engine having rated power of 3.74 kW at 1500 rpm was tested on three samples of ethanol- ethyl acetate- biodiesel substitute fuels using 200^0 proof ethanol containing 10 to 20 per cent ethanol with biodiesel and ethyl acetate. The performance of engine in respect of brake power, fuel consumption and brake fuel consumption, and emission of O_2, CO_2, NO and NO_2 was evaluated to determine compatibility of substitute fuel as fuel for C.I. engine. The results obtained that all the three selected substitute fuel, viz. 200^0-10/0/90, 200^0-15/5/80 and 200^0-20/10/70, had similar power producing capabilities, slightly higher fuel consumption, and lower exhaust emission as those of biodiesel fuel alone. Based on the study use of 200^0-20/10/70 ethanol –ethyl acetate –biodiesel substitute fuel recommended for fuel use in Compression Ignition engines. This substitute fuel may replace 30 per cent biodiesel with user emissions.

Key words: Bio-diesel, Ethanol ethyl acetate

Biodiesel is an alkyl (e.g. methyl, ethyl) ester of fatty acids made from a wide range of vegetable oils, animal fat and used cooking oil via the trans-esterification process. Moreover, biodiesel has been used not only as an alternative for fossil diesel, but also as an additive for diesohol – a blending of ethanol with fossil diesel (Fernando *et al*. 2004 and Chincholkar *et al*. 2005). Effective in the country and all vehicles must meet the specified emissions limits. Alam (2011) reported that biodiesel (fatty acid methyl ester) which is derived from triglycerides by trans-esterification has attracted considerable attention during the past decade as a renewable, biodegradable and nontoxic fuel. Several processes for biodiesel fuel production have been developed, among which trans-esterification using alkali as catalyst gives high level of conversion of triglycerides to their corresponding methyl ester in a short duration. Lokesh (2011) estimated that by 2011, 20 % of bio-energy needs of India should be met by biodiesel. To meet these expectations it would require 12 to 13 million ha of biodiesel feed stock plantations. Currently biodiesel is produced using non-edible oil from trees like *Jatropha curcas*. Jain (2007), reported comparison of PTO performance of tractor fueled with high speed diesel, biodiesel of karanja, soybean and mahua and their blends with high speed diesel engine. This strategy of propagating *Jatropha curcas* as primary biodiesel feed stock has certain drawbacks. This paper addresses the shortcomings in the present strategy and suggests few alternatives. The investigators reported that with the use of vegetable ester as fuel for diesel engines, comparable performance with diesel was achieved (1-6). Most of the oils tried in diesel engines included rapeseed, soybean, sunflower and vegetable oil. These oils are essentially edible oils in the Indian context and use of biodiesel from these oils as a substitute to diesel fuel may be costlier. With the abundance of forest and tree borne non edible oils available in India, not much attempts has been made to use ester of these non edible oils as a substitute for diesel karanja (*Pongamia pinnata*) is one such forest based tree borne non-edible oil with a production potential of 135000 million tonnes diesel and ethanol blending has been made mandatory in the country at 10-15% level mainly because of advantages of reduced emission. In view of above facts, a study was undertaken on the use of stable biodiesel–ethanol blend as a substitute to diesel fuel for energizing diesel engines

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with the following objectives: (i) To optimize the catalyst quantity for production of biodiesel using karanja oil. (ii) To prepare the stable blend of biodiesel and ethanol using stable surfactants. (iii) To determine the fuel properties of stable blends. (iv) To evaluate the short duration performance of 3.74 kW commercial diesel engines and emission characterstistics using stable blend.

MATERIALS AND METHODS

The experiment was conducted in the bio-fuel and Farm Power Laboratories of the Department of Agricultural Energy and Power of Central Institute of Agricultural Engineering (Bhopal), India.

Fuel properties of biodiesel and ethanol stable blends in kinematic viscosity, relative density and API gravity, flash point and fire point following the standard test producer BIS codes in the Biodiesel Laboratory of Agricultural Energy Power Division of Central Institute of Agricultural Engineering (CIAE), Bhopal, India.

The stable substitute fuels as shown in Table 1 were selected as test fuel. The performance of a biodiesel engine on the selected substitute was compared with biodiesel.

The experiments were conducted on preparation of stable substitute of ethanol of different proofs and biodiesel using acetate as surfactant.

Ethyl acetate ($CH_3COOC_2H_5$) is an ester which is derived by the replacement of –OH in the carboxyl group of acetic acid by the ethyl group $–OC_2H_5$. It is a colorless liquid and has characteristic odors of bad apples. Its boiling point temperature and molecular weight and 77° C and 88 respectively

Table 1 Fuel selected for Engine test

Fuel types	Fuel constituents (%)			Biodiesel replacement (%)
	Ethanol	Ethyl acetate	Bio-diesel	
200^0-10/0/90	10	0	90	10
200^0-15/5/80	15	5	80	20
200^0-20/10/70	20	10	70	30

Table 2 Proof of ethanol used for preparation of substitute

Proof of ethanol (°)	Water content (% by volume)	Ethanol (% by volume)
200°	0	100
190°	5	95
180°	10	90
170°	15	85

Table 3 Ethanol-ethyl acetate-biodiesel substitute fuel

Fuel composition code	Fuel constituents (%)			Biodiesel replacement (%)
	Ethanol	Ethyl acetate	Bio-diesel	
200^0-10/0/90	10	0	90	10
200^0-15/5/80	15	5	80	20
200^0-20/10/70	20	10	70	30

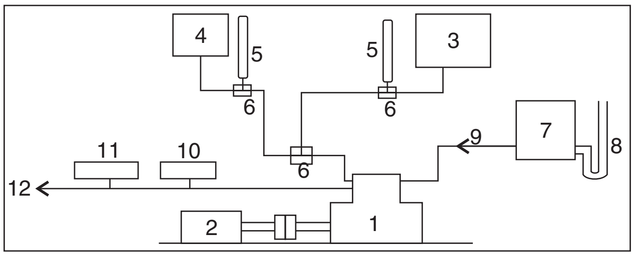
Table 4 Engine specification

Make	Kirloskar
Model	AVI
Rated Brake power (bhp / kW)	5/3.74
Rated speed (rpm)	1500
Number of cylinder	1
Bore × Stroke (mm)	80×110
Displacement volume (cc)	552.920
Compression ratio	16.6:1
Cooling system	Water Cooled
Lubrication system	Forced Feed
Standard injection timing	27° BTDC

A Kirloskar make, constant speed, four stroke, single cylinder, direct injection compression ignition engine of 3.74 kW was used for the study. The specifications of the engine are given in Table 4.

The schematic diagram of the experimental set-up is shown in Fig 1. It consists of the test engine coupled to an eddy current dynamometer along with controller. A SAJ-Froude make, EC-15 model dynamometer was used to load the engine.

The performance test of the engine was conducted as



1. Engine
2. Brake drum dynamometer
3. Fuel tank (biodiesel)
4. Diesel tank
5. Burettes
6. Three way valve
7. Air box
8. Manometer
9. Air flow direction
10. Exhaust analyzer
11. Smoke meter
12. Exhaust flow

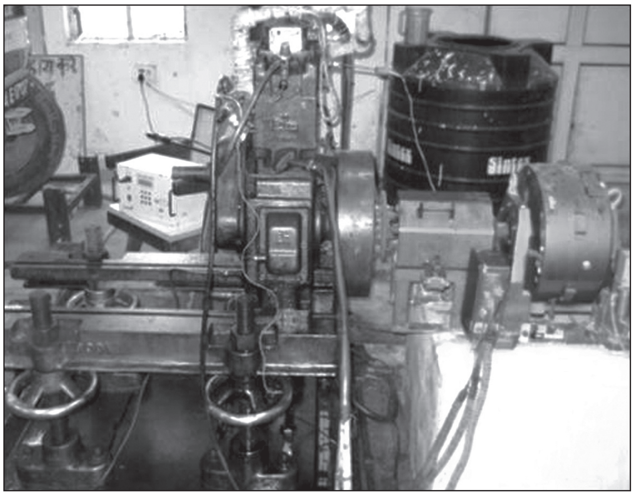


Fig 1 Experimental set-up

per IS: 10000 [P: 5]:1980. Initially the engine was run on no load condition and its speed was adjusted to 1500 ± 10 rpm by adjusting the screw given with the fuel pump rack. The corresponding torque to be applied to the engine when delivering rated power (3.73. kW) at rated speed of 1500 rpm was calculated using the equation given below:

$$kW = \frac{N \times T}{9549.305}$$

where, kW, Power (Kilo watt); N, Number of revolutions (RPM); T, Torque (N-m).

Engine speed: The engine speed (rpm) as displayed by the electronic controller unit (Fig 1) of eddy current dynamometer was recorded during the course of experiment at different loading conditions of the engine.

Engine break power: The break power developed by the engine was calculated using the following equation.

$$BP = \frac{NT}{C}$$

where, BP, Brake horse Power, kW; C, Constant value, 63025.

Fuel consumption: The fuel consumption was measured with the help of a SAJ-Froude make, SFV-75 model electronic volumetric fuel consumption measuring unit. It consisted of a fuel tank, graduated glass pipette of 25, 50 and 75 ml, a solenoid value, photo sensor assembly and timer. The fuel to the consumption of allowed passing through the 25 ml pipette the time taken for them. Consumption of 25 ml fuel was noted by means of a timer provided with the unit. The break specific fuel consumption was calculated by using the relationship as given below:

$$Bsfc = \frac{Vcc \times p \times 3600}{BP \times t}$$

where, bsfc, Brake specific fuel consumption, g/kW-h; Vcc, Volume of fuel consumed; cc, ρ = Density of fuel, g/cc; t, Time taken to consume, cc of fuel, sec.

Measurement of exhaust emission: The emission of oxygen, carbon dioxide and nitrogen dioxide, Nitric oxide through exhaust under different fuels were also measured in engine exhaust gases emanating from burning of different fuel sample was measured with the help of an exhaust gas analyzer. The sample drawn from the exhaust pipe of the engine using 3 mm diameter PVC pipe through a pump operating on 230V AC was fed into the electrochemical sensor of the analyzer. The measurements were made under different load conditions.

RESULTS AND DISCUSSION

The final product of biodiesel from Karanja oil is used as an alternative fuel to operate Diesel engine in the CIAE Engine Laboratory. The engine has been run using biodiesel and required data are collected to calculate the engine performance parameters. Studies on stability of substitute fuel prepared containing anhydrous and aqueous ethanol and biodiesel using ethyl acetate as surfactant were conducted. The phase separation and homogeneity of substitute were observed at room temperature and at 35 and 45^{0}C temperature. The 200^0-10/0/90, 200^0-15/9/76 and 200^0-20/10/70, substitute fuel stable were selected as fuel for constant speed C.I. engine. A stationery 3.74 kW (5 bhp) constant compression ignition engine was tested on diesel and three selected substitute fuel. The engine performance in respect of brake power, fuel consumption and brake specific fuel consumption, emissions of O_2, CO_2, NO_2 and NO was evaluated (Table 6).

Based on the study, the following results were as shown in Table 5 and 6.The ethanol –ethyl acetate – biodiesel substitute fuel prepared using 200^0 proof ethanol and designated as 200^0-10/0/90, 200^0-15/5/80 and 200^0-20/10/70, were found stable at the selected temperature

Table 5 The properties of karanja oil and ethanol proof and biodiesel

Fuel notation	Relative density	Kinematic viscosity at 30°C	API gravity	Flash point (°c)	Fire point (°c)
Biodiesel	0.8888	25.7	27.7	164	169.2
Ethyl acetate	0.9062	24.9	24.6	-0.5	5.0
		Ethanol proof			
Ethanol 200^0	0.7923	27.6	47.1	16.7	21.5
Ethanol 190^0	0.8113	27.9	42.9	18.2	23.8
Ethanol 180^0	0.8265	27.9	39.7	20.2	26.3
Ethanol 170^0	0.8416	28.2	36.6	20.8	26.7
		Substitute fuel			
200^0-10/0/90	0.8820	12.7	28.9	38.0	43.5
200^0-15/5/80	0.8750	11.0	30.2	25.4	30.8
200^0-20/10/70	0.8740	6.6	30.3	22.5	27.3

Table 6 Observed value of different parameters at full load

Parameter	Substitute fuel		
	200^0-10/0/90	200^0-15/5/80	200^0-20/10/70
Torque (N-m)	23.36	23.36	23.36
Engine rpm	1502 ± 3.000	1506 ± 1.528	1503 ± 1.528
Brake power (kW)	3.674 ± 0.007506	3.684 ± 0.005033	3.676 ± 0.004041
Fuel consumption (l/h)	2.037 ± 0.006	2.001 ± 0.004	2.071 ± 0.002
BSFC (g/kW-h)	365.000± 1.155	357.000 ± 1.155	369.000 ± 0.577
Emission of O_2 (%)	3.133 ± 0.208	4.0 ± 0.000	4.000 ± 0.000
Emission of CO_2 (%)	5.567 ± 0.153	4.0 ± 0.000	4.067 ± 0.058
Emission of NO_2 (ppm)	614±1	625±1	607±1
Emission of NO (ppm)	679.667± 2.082	625.000± 1.000	605.667± 3.055

*Values, Mean±SD; SD, standards deviation conditions. The compatibility of substitute on the basic of fuel properties suggested that ethanol of 200^0 proof may be used for preparation of ethanol- biodiesel substitute fuel using ethyl acetate as surfactant. The brake power of the engine was found to increases with increases in brake load under all fuel types tested.The engine speed developed by the engine at full load on 200^0-10/0/90, 200^0-15/95/80, and 200^0-20/10/70 substitute fuel was found to be1502 ± 3.000, 1506 ± 1.528 and 1503 ± 1.528 The brake power developed by the engine at full load on 200^0-10/0/90, 200^0-15/95/80, and 200^0-20/10/70 substitute fuel was found to be 3.674 ± 0.007506, 3.684 ± 0.005033 and 3.676 ± 0.004041, respectively. The substitute fuel of ethyl acetate-biodiesel was found to be having similar power producing capabilities as biodiesel under each load conditions.

The fuel consumption of the engine on all load types tested was found to increase with increase in brake load. The fuel consumption of the engine on all fuel types was found to be 2.037 ± 0.006 l/h (maximum) at 100 percent brake load. The fuel consumption of the engine at full load on 200^0-10/0/90, 200^0-15/9/76, and 200^0-20/10/70 substitute fuel were found to be as 2.037 ± 0.006, 2.001 ± 0.004and 2.071 ± 0.002l/h.The brake specific fuel consumption (BSFC) of the engine was found to decrease with increase in brake load and was found maximum at 20 percent brake load on all fuel types tested. This BSFC of the engine on diesel 200^0-10/0/90, 200^0-15/9/76, and 200^0-20/10/70 substitute fuel at full load were found to be 365.000 ± 1.155, 357.000 ± 1.155 and 369.000 ± 0.577g/kW–h respectively. The emission of oxygen (O_2) from the exhaust of engine was found to increase with decrease in brake load. The emission of O_2 was found to 3.133 ± 0.208, 4.0 ± 0.000 and, 4.000 ± 0.000 per cent on 200^0-10/0/90, 200^0-15/9/76, and 200^0-20/10/70 substitute fuel respectively. The emission of carbon dioxide from the exhaust of engine was found to decrease with increase in brake load. The emission of CO_2 was found to vary from 5.567 ± 0.153, 4.0 ± 0.000, and 4.067 ± 0.058, percent respectively on 200^0-10/0/90, 200^0-15/9/76, and 200^0-20/10/70, substitute the emission of carbon dioxide from the exhaust of engine was found to decrease with increase in brake load. The emission of nitrogen dioxide was found to decrease to increases in brake load under all types tested and was found to be brake load. The emission of NO_2 was found 614 ± 1, 625 ± 1, and 607 ± 1, ppm respectively on 200^0-10/0/90, 200^0-15/9/76, and 200^0-20/10/70 substitute fuel. The emission of nitric oxide (NO) was found to increase with increase in brake load under all fuel types tested and it decreased on substitute fuel. The emission of NO on 200^0-10/0/90, 200^0-15/9/76, and 200^0-20/10/70, substitute fuel was found to 679.667 ± 2.082, 625.000 ± 1.000 and 605.667 ±3.055 ppm respectively.

A Compression Ignition engine having rated power of 3.74 kW at 1500 rpm was tested on three samples of ethanol-ethyl acetate-biodiesel substitute fuels using 200^0 proof ethanol containing 10 to 20 per cent ethanol with biodiesel and ethyl acetate. The performance of engine in respect of brake power, fuel consumption and brake fuel consumption, and emission of O_2, CO_2, NO and NO_2 was evaluated to determine compatibility of substitute fuel as fuel for C.I. engine. The results obtained that all the three selected substitute fuel, viz. 200^0-10/0/90, 200^0-15/5/80 and 200^0-20/10/70, had similar power producing capabilities, slightly higher fuel consumption, and lower exhaust emission as those of biodiesel fuel alone. Based on the study use of 200^0-20/10/70 ethanol–ethyl acetate–biodiesel substitute fuel recommended for fuel use in Compression Ignition engines. This substitute fuel may replace 30 per cent biodiesel with user emissions.

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