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Performance and Emission Characteristics of C.I Engine Fuelled with Hybrid Biodiesel

Veerbhadrappa Telgane[a,d], Sharanappa Godiganur[a], N. Keerthi Kumar[b] and T.K. Chandrashekar[c]

[a]*School of Mech. Engg., REVA University, Bengaluru, Karnataka, India*
[b]*Dept. of Mech. Engg., BMS Institute of Tech. and Management, Bangalore, Karnataka, India*
[c]*Dept. of Mech. Engg., MIT Mangaluru, Karnataka, India*
[d]*Corresponding Author, Email: Veerbhadrappa@reva.edu.in*

ABSTRACT:

In the present experimental investigation, the performance and emission characteristics of four stroke single cylinder water-cooled DI diesel engine using dual hybrid biodiesel is evaluated. Dual hybrid biodiesel produced from Simarouba Oil Methyl Ester (SuOME) and Jatropha Oil Methyl Ester (JOME) is used as a fuel to run the engine. Both the methyl esters are mixed in equal % and blended with diesel (B20 to B100). The fuel properties such as kinematic viscosity, calorific value, flash point, carbon residue and specific gravity were found for the prepared biodiesel. The results showed that B20 has almost closer brake thermal efficiency compared to that of the conventional diesel fuel. Except NO_x, B100 has recorded very less emission of CO, CO_2 and HC compared to that of diesel fuel.

KEYWORDS:

Hybrid biodiesel; Simarouba Oil Methyl Ester; Jatropha Oil Methyl Ester; Diesel engine; Performance; Emission

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NOMENCLATURES:

B20	10% JOME, 10% SuOME and 80% diesel by volume
B40	20% JOME, 20% SuOME and 60% diesel by volume
B60	30% JOME, 30% SuOME and 40% diesel by volume
B80	40% JOME, 40% SuOME and 20% diesel by volume
B100	50% JOME and 50% SuOME

1. Introduction

Energy plays a substantial role in enhancing economic development of any country and the demand for conventional fuels remains to upsurge over the decades. The exhaustion of world oil reserves leads to search for better promising alternative substitute [1]. In this regard, it is anticipated that originated fuels will replace 20% of conventional diesel fuels by 2022. Biodiesels are produced from both edible and non-edible feedstock but the use of edible oil may cause scarcity of edible oil globally [2]. Hence, biodiesel produced from non-edible feedstock has been considered as a better substitute for diesel fuel. Though it is true, many factors like adequacy, type and harvesting capacity of plants has to be considered [3], biodiesels produced from various feedstocks may have different advantages. Hence, in the recent days it is necessary to obtain the benefits of biodiesels produced from one or more feedstock. Many researchers have adopted the concept of mixing of biodiesels with Jatropha and sesame oil methylesters at different ratios to run the diesel engines. It has been observed that due to mixing of two different feed stocks, there is an enhancement in physicochemical properties.

There is also an increase in heating value with reduced viscosity of blends relative to biodiesel produced from single feedstock. Results also revealed that, there is a reduction in CO and other emissions with slight increase in Brake Specific Fuel Consumption (BSFC). In general, it is observed that use of biodiesel up to 40% with diesel fuel in engine gives the results close to those of diesel fuels. Bora et al [4] made use of biodiesel produced from three different feedstock namely, polonga, koroch and Jatropha curcas, to study the performance of diesel engine. The results showed reduced performance compared to diesel fuel. However, mixed biodiesel showed that it had superior engine performance when compared to individual biodiesels. Further, reduction in BSFC of 3.65, 0.51 and 3.64% is observed when polonga, koroch and Jatropha curcas biodiesel is respectively used. Same trend is observed for CO, HC and smoke opacity with reverse trend for the brake thermal efficiency (BTE).

Padhee et al [5] reported that blending 20% Jatropha curcas biodiesel with diesel fuel results in higher BTE and exhaust gas temperature (EGT) but lower BSFC due to its higher viscosity and oxygen content. In addition, the CO emission is lower for all Jatropha curcas biodiesel-diesel blends. However, the nitrogen oxide (NO_x) emissions are higher for these blends. Vedharaj et al [6] analyzed the engine performance for 25% and 50% blends of ceiba pentandra. Higher BTE is observed with B50 due to higher combustion temperature and therefore NO_x emission increases. To reduce the NO_x emissions, urea-selective non-catalytic reduction system is adopted in the exhaust pipe. Simarouba biodiesel has been explored by many researchers as a potential substitute for diesel fuel. Ram et al [7] had studied the physical properties of Simarouba fruit and concluded that Simarouba biodiesel can be a better substitute for diesel fuels. Keerthi et al [8] had used Simarouba oil methyl ester to study the effect of different combustion chamber. Due to higher viscosity of Simarouba oil compared to diesel fuel, it is observed that there is a reduction in performance of the engine. To increase the engine performance, various combustion chamber shapes have been adopted.

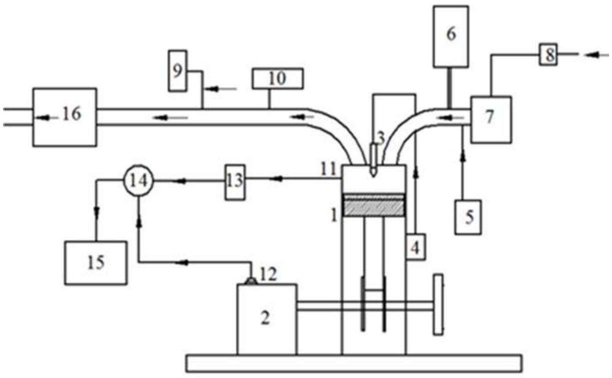
Even though many studies have been carried out concerning diesel engines and use of biodiesel, there is a lack of studies on the mixture of Jatropha and Simarouba biodiesel. In this paper, an in-depth investigation is carried out on the engine performance and emissions of biodiesel-diesel fuel blends at a ratio from 105 to 50% Jatropha curcas-Simarouba biodiesel. These test fuel samples are designated as B20, B40, B60, B80, and B100. The engine performance namely SFC, BTE and emission characteristics like CO, CO_2, HC, O_2 and NO_x are investigated for these biodiesel blends.

2. Materials and methodology

In the first phase of the work, esterification of selected oils and mixing of both the oil was done on volume basis and their properties have been evaluated. In the second phase, experiments were conducted using hybrid biodiesel blended with diesel for different blend ratio and also with neat diesel fuel. All the blend ratios were tested for different loading conditions and engine performance measurements such as brake specific fuel consumption, and emissions were measured to evaluate and compute the behaviour of diesel engine. Average reading of three runs was taken for tabulating the results. Initially, combustion and emission characteristics of test engine were investigated using conventional diesel fuel under standard operating conditions for different loads starting from no load to full load conditions. In the second phase of the work, hybrid fuel has been prepared by mixing Jatropha and Simarouba biodiesel in the ratio of 50% each, and blended with diesel in 20, 40, 60, 80 and 100%. Using the prepared fuel further tests was carried out to obtain the performance and emissions characteristics of engine when operated using test fuel. Average of three set of reading was considered to plot the graph. Finally, the results like BTE, BSFC, along with emissions like smoke capacity, HC, CO and NO_x were compared with baseline data and analyzed.

3. Experimental setup

The schematic of experimental engine test rig setup used for evaluation of performance, combustion and emission characteristics of hybrid fuel at standard operating conditions is shown in Fig. 1. Technical specifications of the engine setup used for present study are given in Table 1. The speed and torque of the engine is controlled automatically by an eddy current dynamometer. A hart-ridge smoke meter and delta 1600 S exhaust Gas analyzer was suitably employed to determine the regulated emission levels such as HC, CO and NO_x which uses non-dispersive infrared technology. Gas analyzers were initially calibrated before the start of trial tests. The in-cylinder pressure was obtained by using a piezo-electric type pressure sensor mounted on the head of engine cylinder. Table 2 shows the physico-chemical properties of test fuels used.



1. CI Engine, 2. Dynamometer, 3. Fuel Injector, 4. Fuel pump, 5. Fuel filter, 6. Fuel tank, 7. Air stabilizer tank, 8. Air filter, 9. Smoke meter, 10. Exhaust gas analyzer, 11. Pressure sensor, 12. TDC encoder, 13. Charge amplifier, 14. Indimeter, 15. Computer, 16. Exhaust pipe

Fig. 1: Line diagram of experimental setup

Table 1: Kirloskar TV 1 Engine and dynamometer specifications

Parameter	Specifications
Nozzle opening pressure	200 to 225 bar
Governer type	Mechanical centrifugal type
No. of cylinders	Single cylinder
Compression ratio	16.5:1
Bore diameter	80mm
Stroke length	110mm
Dynamometer	Electrical

Table 2: Physico-chemical properties of the crude Jatropha methyl ester (JOME) and Simarouba oil methyl ester (SuOME)

Property	Diesel	JOME	SuOME	B100
Density (kg/m^3)	840	876	865	875
Viscosity (mm^2/s)	2.98	4.8	4.68	4.72
Flash point (°C)	74	170	165	166
Calorific value (kJ/kg)	45,500	36,096	37,933	39,934
Acid value	0.35	4.9	5.34	5.02

4. Results and discussion

Studies were conducted on methyl esters of Jatropha and Simarouba dual biodiesel B100 and blends of B20, B40, B60 and B80. The fuel consumption test and rating test of a constant speed C.I engine was also conducted to evaluate the performance of the engine on diesel and different blends of biodiesel. Variations of BSFC in engine with various load for hybrid and diesel fuel is shown in Fig. 2. BSFC is inversely proportional to thermal efficiency of an engine. BSFC decreases sharply with the increase in load for all fuels. The main reason for this could be the increase in fuel which is required to operate the engine with increase in brake power because of its relatively less amount of heat lost at higher loads. The main reason for the variation of BSFC is the properties like density, viscosity and calorific value of the fuel used [9]. BSFC is lower for diesel fuel due to its lower viscosity than the hybrid fuel. However, B80 showed reduced BSFC than other blends and this may be attributed to higher combustion temperature of previous cycle leads to reduce the mixing time hence complete combustion happens.

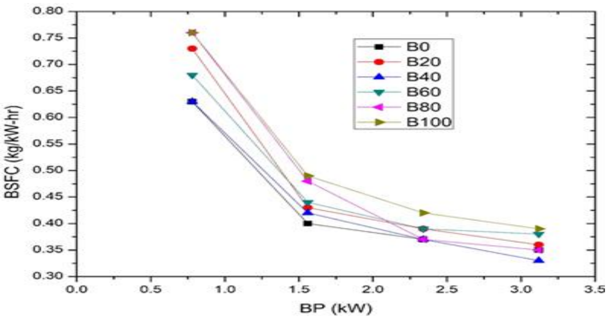


Fig. 2: Variation of BSFC with load

From Fig.3, the BTE of all the tested fuel increases with increase in brake power. This is due to the reduction in heat loss and increase in power and load. BTE for conventional diesel is found to be the highest because of its higher calorific value and proper air-fuel mixing. Hence, it results in complete combustion. It can be also observed that B20 and B100 exhibit highest and lowest BTE respectively when compared with all hybrid fuels. BTE of B20 and B100 is 26.5% and 24.2% respectively. This may be due to additional lubricity offered by B100 than B20, as a result of marginally higher viscosity of B100 test fuel.

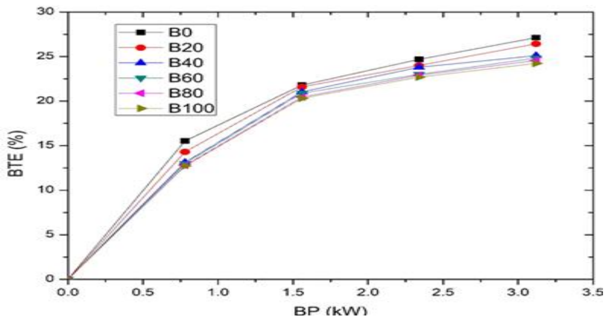


Fig. 3: Variation of BTE with load

Variation of CO emissions with engine loading for different test fuels is compared in Fig. 4. The major reason for CO emissions is lack of oxygen content in fuel air mixture [10]. It can be observed that, CO reduces drastically at a load of 10 and 15 N-m for all the test fuels. CO emissions for diesel fuel are 0.08% at a load of 15N-m whereas CO emissions for all other blends are lesser than that of diesel fuel. The lower CO emission of biodiesel blends maybe due to their more complete oxidation as compared to diesel. Some of CO produced during combustion of biodiesel may have converted into CO_2 by taking up extra oxygen molecules present in biodiesel chain and thus reduced CO formation. However CO emissions for B100 is 0.06% at 80% load whereas for B20 CO emission is same as diesel fuel and this may be attributed as % of biodiesel increases in diesel fuel, it leads to increase in oxygen content with in the combustion chamber due to rich oxygen content of hybrid fuel. The hydrocarbon emission trend for various blends of biodiesel is represented in Fig. 5. The reduction in HC was linear with the addition of biodiesel in the tested blends. These reductions indicate a more complete combustion of the fuel. The presence of oxygen in the fuel was thought to promote complete combustion.

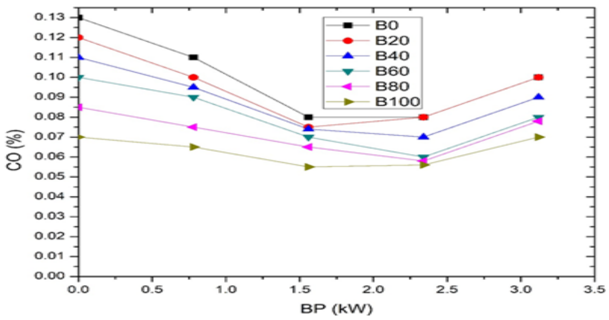


Fig. 4: Variation of CO with load

Fig. 6 shows the variation of CO_2 with respect to load. It is observed that as the load increases, CO_2 emission increases for all the test fuel. CO_2 emission from the engine using diesel fuel is 10% whereas for all other hybrid test fuels it is higher. This may be attributed to complete combustion due to the higher oxygen present in combustion chamber. CO_2 emission for B20 is 10.02% whereas for B100 is 11.25%. This may be attributed to lower calorific value of biodiesels as increase in percentage of blend leads to higher fuel consumption. The variation of NO_x with engine load for different fuels is represented in Fig. 7. NO_x formed in an engine is highly dependent on combustion temperature along with concentration of oxygen present in combustion products. In general, NO_x concentrations vary linearly with load of the engine. As the load increases, the overall air-fuel ratio increases resulting in increase in average gas temperature in the combustion chamber. Hence NO_x formation which is sensitive to temperature increases. The maximum NO_x emission for biodiesel is found to be 1312 ppm for B100 blend. It is 122 ppm higher than that of diesel fuel. The NO_x emissions may be eliminated by exhaust gas treatment.

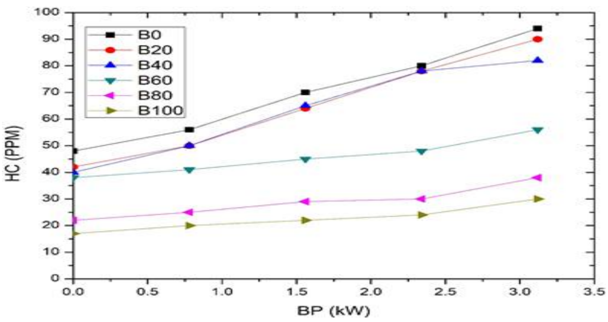


Fig. 5: Variation of HC with load

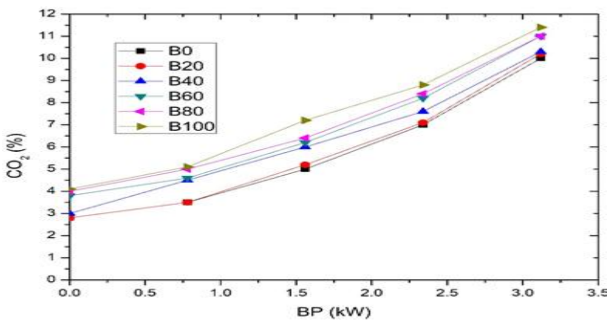


Fig. 6: Variation of CO_2 with load

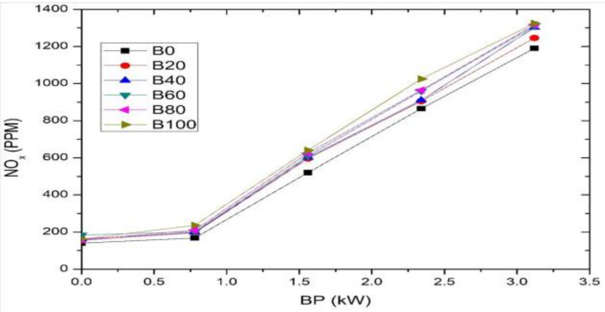


Fig. 7: Variation of NO$_x$ with load

5. Conclusion

Performance and emission results of single cylinder CI engine with hybrid mode of operation (SuOME and JOME) blended with diesel fuel were compared with baseline engine results. The production of dual (hybrid) biodiesel of non-edible oils involves a 2-stage transesterification process. Smooth engine operation has been observed for hybrid fuel operation compared to diesel fuel operation. The maximum BTE is found to be 26.43% for B20 blend which is 0.69% lesser than that of diesel. The minimum BSFC of biodiesel is found to be 0.33 kg/kWh for B40 blend which is almost equal to that of diesel. The minimum CO emission for biodiesel is found to be 0.05 ppm for B100 blend which shows a 41.5% reduction as compared to diesel. The minimum HC emission for biodiesel is found to be 17 ppm for B100 blend which shows a 70.2% reduction as compared to diesel. CO_2 emission increases linearly as the load increases. The maximum CO_2 emission was found in B100 because of complete combustion of fuel. The maximum NO_x emission for biodiesel is found to be 1312 ppm for B100 blend. Use of hybrid fuel may reduce hazardous emission and may become a substitute for conventional diesel.

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