Journal of Scientific & Industrial Research
Vol. 67, January 2008, pp.73-76

Performance of a mixed biodiesel fueled diesel engine

Dilip Kumar Bora[1], L M Das[1] and M K Gajendra Babu[2]

[1]Centre for Energy Studies, Indian Institute of Technology Delhi, New Delhi 110 016
[2]Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai

Received 06 March 2007; revised 23 October 2007; accepted 25 October 2007

This study presents application of biodiesel produced from the mixture of polanga oil (*Calophyllum inophyllum*), karanja oil (*Pongamia pinnata*) and jatropha oil (*Jatropha curcas*) in CI engines and compares biodiesel performance and emissions characteristics with petro diesel.

Keywords: B20, Biodiesel, Jatropha oil, Karanja oil, Polanga oil, Transesterification

Introduction

Biodiesel can be blended to any level with petro diesel to create a biodiesel blend, which in compression ignition (CI) engine essentially requires very little or no engine modifications because biodiesel has properties similar to petro diesel fuels[1-3]. B20 (a blend of 20% by vol of biodiesel with 80% by vol of petro diesel) has demonstrated significant environmental benefits in US with a minimum increase in the cost for fleet operations and other consumers[4]. No significant engine problems were reported in large-scale tests with urban bus fleets running on B20.

In present work, mixture of polanga oil (*Calophyllum inophyllum*), karanja oil (*Pongamia pinnata*) and jatropha oil (*Jatropha curcas*) in equal volume was selected for development of the appropriate biodiesel to use in diesel engine.

Materials and Methods

Karanja and jatropha oils were purchased from Kaldas Oil Mill, Udaiapur. Polanga oil was taken from Orissa. Methanol and sulfuric acid were purchased from Merck.

Acid Catalyzed Esterification Reaction

In a 500 ml round bottom flask, per batch of 300 ml mixture of high free fatty acid (FFA) polanga, karanja and jatropha oils with 30% v/v of methanol to oil ratio and 0.5% v/v of sulfuric acid to oil ratio was taken. Flask was sealed to prevent alcohol to escape. Mixture was stirred at a constant speed of 700 rpm at 50°C. Sample (5 ml) was collected from reaction vessel and titrated against KOH for FFA level reduction at 5 min intervals for the first 30 min, and thereafter at 30 min intervals. After 1 h, contents were poured in a separating funnel for separating lower layer (triglyceride) and remaining portion was transesterified using base catalyst.

Transesterification Reaction

In esterified oils (6 l), taken in reactor (10 l), alcohol (1.3 l) and KOH (60 g) were added. Mixture was stirred at a constant speed of 700 rpm at 70°C. Reaction was conducted for 3 h and then mixture allowed to settle down in a separating funnel. Upper layer (biodiesel) was washed with water and vacuum distilled to remove moisture. Ester was then blended with petro diesel for preparing biodiesel blends (B20, B40, B60, B80 and B100) to be used in CI engine.

Diesel Engine Experimental Set-up

Kirloskar single cylinder (DAF 8), four stroke, vertical, air cooled, direct injection diesel engine was used with following specifications: bore, 87.5 mm; stroke, 110 mm; compression ratio, 17.5:1; speed, 1500 rpm; brake power, 8/5.9 bhp/kw; displacement volume, 779.704 cc; and injector opening pressure, 200 bar.

Engine was coupled to a 5 KVA electric generator through which load was applied by increasing field voltage. Engine was tested at no load, 20, 40, 60, 80, and 100% brake load conditions. During experiments, engine

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*Author for correspondence
E-mail: dilipboraesz@rediffmail.com

Table1 — Specification of diesel and biodiesel

Property	Diesel	Mixture of polanga, karanja and jatropha oil (2 l each)	Biodiesel produced from mixture of polanga, karanja and jatropha oil (B 100)
Specific gravity	0.856	0.925	0.870
Kinematic Viscosity @ 40 ºC, cSt	2.246	35.43	4.89
Calorific value, MJ/kg	43.68	39.18	38.67
Cloud Point, °C	-6	10	-2
Pour Point, °C	-16	4	-6
Flash Point, °C	76	260	163
Copper strip corrosion @ 100 °C, for 3 h	-	-	1a
Acid value, mg KOH/g	0.54	35	0.60
Sulphur content, ppm	349	-	13
Carbon residue, %wt	0.015	0.30	0.03
Moisture, %wt	-	0.28	0.025
DistillationIBP/FBP(°C)	176/ 306	-	215/ 357
Saponification value, mg/g	-	202.1	-

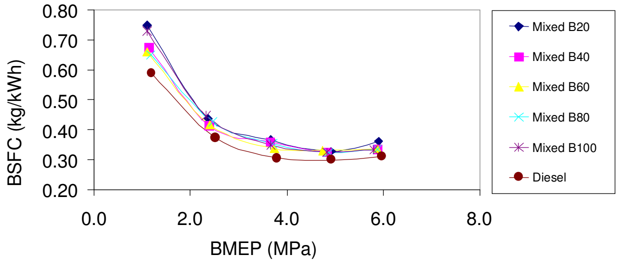

Fig. 1—Brake specific fuel consumption for different diesel-biodiesel fuel blends and diesel

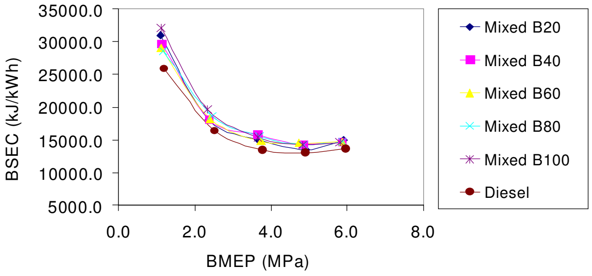

Fig. 2—Brake specific energy consumption for different diesel-biodiesel fuel blends and diesel

speed, fuel consumption, air consumption rate and exhaust gas temperature were recorded. Emission tests were carried out with portable pollution monitor of AVL make (model 4000 Di-Gas Analyzer) for CO, CO_2, O_2 and NOx. AVL make Smoke Meter (Model 437) was used to measure smoke opacity of exhaust gas.

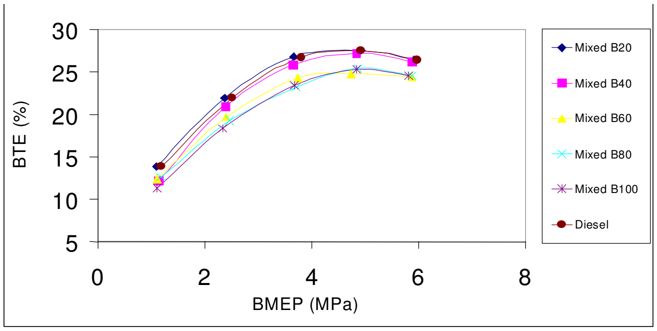

Fig. 3— Brake thermal efficiency for different diesel-biodiesel fuel blends and diesel

Results and Discussion

Biodiesel derived from mixture of polanga, karanja and jatropha oils has been found to meet ASTM D-6751 specifications (Table 1).

Engine Performance

Brake specific fuel consumption (BSFC) values of blends were slightly higher than those of diesel fuel at all loads (Fig. 1). Higher blending is needed to produce same amount of energy due to its higher specific gravity and lower heating value in comparison to diesel fuel. BSEC versus brake mean effective pressure (BMEP) for all selected blends and diesel fuels (Fig. 2) show that as load increases, BSEC decreases for all fuel blends. Higher BSEC of blends may be an indication of higher density and lower calorific value of biodiesel compared to those of diesel.

Presence of oxygen in mixed biodiesel (up to 40%) improves combustion of fuel (Fig. 3). Further increase of mixed biodiesel in diesel decreases thermal efficiency due to poor combustion characteristics of blends owing to their relatively high viscosity and poor volatility that overcomes excess oxygen present in biodiesel.

Exhaust gas temperature (EGT) increased with increase in load for all the cases (Fig. 4). EGTs of biodiesel are similar with diesel, because nearly same quantity of fuel is consumed per hour for both diesel and biodiesel blends in each load setting of the engine. Since heat loss to the exhaust on percent basis was approx. constant throughout the entire load range hence same quantity of fuel consumed means same heat was dejected, resulting in little variation in EGT.

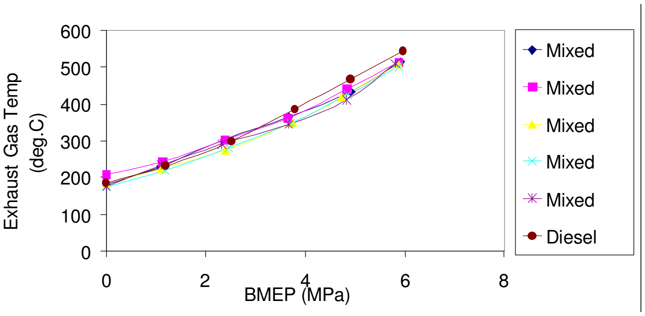

Fig. 4— Exhaust temperature for different diesel-biodiesel fuel blends and diesel

Emission Characteristics

As cetane number of ester-based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion. Therefore, oxygen content and cetane number of diesel-biodiesel blends lead to lower hydrocarbon emissions as compared to diesel fuel (Fig. 5a). Similar observation was reported by Usta[5].

Increase in local temperature and oxygen concentration within the fuel spray envelope at increasing power level favours a higher level of NOx emissions (Fig. 5b), which were slightly higher than those for diesel fuel at both full and partial loads. Presence of oxygen with blend causes higher NOx emissions, especially at full load. Another indicator for NOx formation is EGT, which increases with increasing ratio of biodiesel in blends. CO emissions increased with increase in load (Fig. 5c). This is typical with all IC engines since air-fuel ratio decreases with increase in load. CO emissions decrease for blended fuels at higher loads, due to enrichment of oxygen owing to biodiesel addition, as increasing the proportion of oxygen will promote further oxidation of CO during engine exhaust process. CO emission levels decrease with increasing

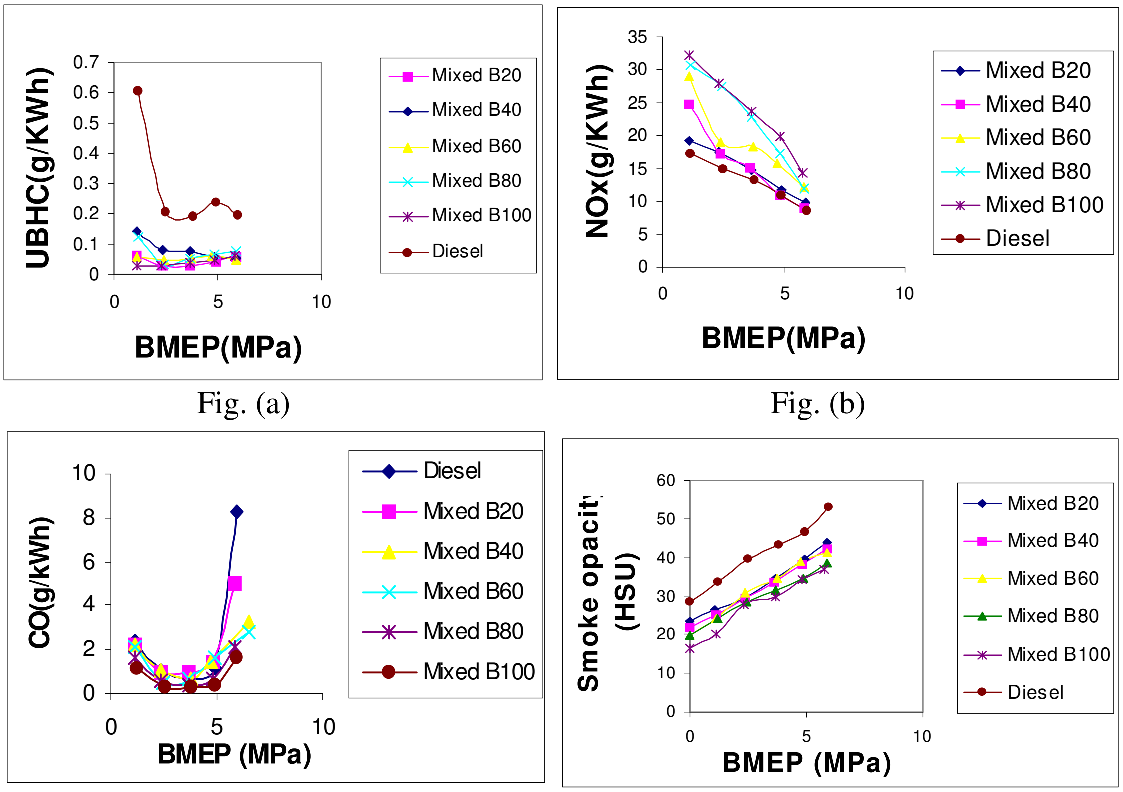

Fig. (a) Fig. (b)

Fig. (c) Fig. (d)

Fig. 5— Emission characteristics: (a) UBHC vs BMEP; (b) NOx vs BMEP; (c) CO vs BMEP; (d) Smoke opacity vs BMEP

biodiesel percentage in the fuel[6]. Smoke density with biodiesel blends was lower than with diesel fuel (Fig. 5d). Higher brake power indicates improved combustion of fuel, implying lower levels of unburned hydrocarbons would be present in engine exhaust, giving lower smoke density levels with biodiesel blends as compared to diesel.

Conclusions

Use of mixed biodiesel (polanga, karanja and jatropha oils) in a conventional diesel engine indicates that performance characteristics of engine with mixed biodiesel operation are comparable to those with neat diesel operation. Major pollutants (CO, smoke, NOx) showed marked reduction over the entire range of experiments. Existing design of diesel engines doesn't need any substantial modification and can be easily converted to biodiesel operation.

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