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Performance Evaluation of a 5 hp Diesel Engine Fueled with Blended Biodiesel of Benola Oil

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Abstract

In this communication, methyl ester of Benola oil was prepared by transesterification using solid potassium hydro-oxide as catalyst and used in a 5 hp single cylinder four stroke diesel engines. Tests were performed at different load conditions and the performance was analyzed for B5 to B30 blends of Benola biodiesel and pure mineral diesel. It was concluded that the lower blends of biodiesel enhance the break thermal efficiency and reduce the fuel consumption. It was also noticed that it reduces carbon pollution but slightly increases the NO_x.

Keywords

Benola oil, Transesterification, Engine performance

Nomenclature:

A	Cross sectional area of the Orifice (m2)	N	Engine Speed (rpm)
BP	Brake Power (kW)	sfc	Specific fuel consumption (Kg/kW-hr)
C.V	Calorific Value (kJ/Kg)	T	Frictional torque (N.m)
C_d	Coefficient of discharge of Orifice	W	Load on engine (kg)
D	Diameter of the Dynamometer drum	ρ	Density of the fuel used (gm/cc)
t	Diameter of thickness (m)	η Vol	Volumetric efficiency (%)
d	Bore diameter (mm)	η_{bth}	Brake thermal efficiency (%)
FP	Friction Power (kW)	η_{mech}	Mechanical efficiency (%)
g	Acceleration due to gravity (m/sec2)		
IP	Indicated Power (kW)		
L	Stroke length (mm)		
m	Mass of fuel consumption (Kg/hr)		

1. Introduction

The application of vegetable oil was first used by the inventor of diesel engine i.e. Rudolf Diesel at the time of first and quoted that, “The use of vegetable oils as engine fuel may seem negligible today. Nevertheless, such oils may become, in the passing years, as important as oil and coal tar presently.” [1]

Monyem et al. [2] stated that the coal dust was used as a fuel in the same diesel fueled engine and achieved high performance. In later age the application of diesel engine increased by vertical growth as its demand increased in automobiles and industries. Richard et al. [3] analyzed CI engine performance which was operating on biodiesel blends (B20) and indicated the little difference in performance between biodiesel and pure diesel. A similar experiment on mahua (Madhuca indica) biodiesel for performance analysis on a compression ignition engine was carried out by Raheman and Ghadge [4]. Many experimental works were carried out for Performance of IC engine by using Karanja oil, fish oil, fats, sunflower oil, canola oil, olive oil, waste oil, Soyabean oil, Thumba oil, Cotton seed oil, and Algae oil [5-18].

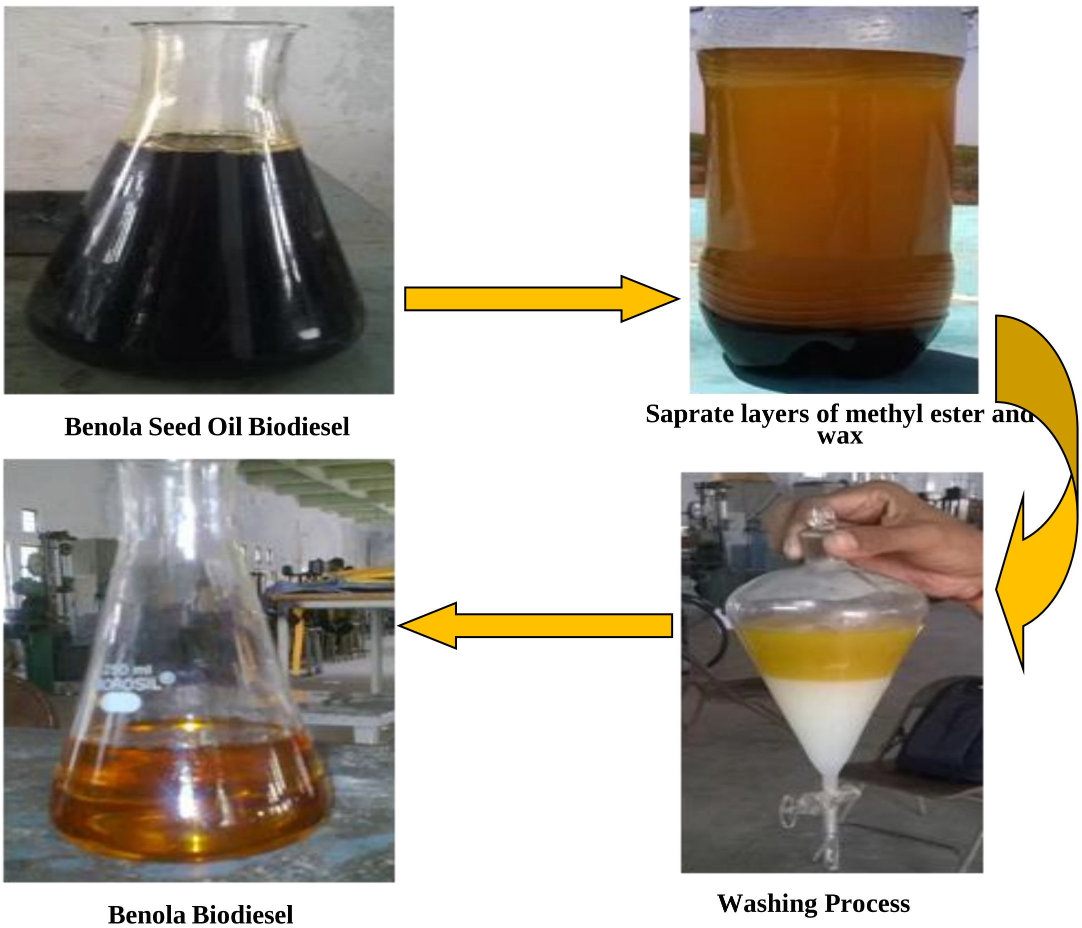

Figure 1. Stages of Benola biodiesel producing

India is ready for biodiesel revolution. As per the [19] government of India is working on nationalized biodiesel mission. The bio-oils cause operational and durability problems for long term storage when it is used without mixing in diesel. These problems are endorsed to low volatility, high viscosity and polyunsaturated characteristics of bio-oils. The process of transesterification is an effective method of reducing bio-oil viscosity and eliminating operational and durability problems.[20]. Several researchers [21-29] have been using biodiesel as an alternate fuel in the existing CI engines without any modification. In the present paper, Authors did the experimental study for performance test of 5hp diesel engine at variable loads conditions using Benola biodiesel which produced in the laboratory and pure diesel.

2. Material and Methods

2.1. Esterification of Benola oil

Benola (Cotton seed) is primarily used to produce Benola oil. It contains a high level of saturated fat and has a high level of pesticides residue as well; hence it is not healthy for human consumption. The benefits of Benola oil are mainly viable from a manufacturing standpoint. It has an incredibly long shelf life and also a high smoke point (450 degree). The Crude Benola oil is first heated to 60°C in a vessel. Then the oil is reacted with Methanol in presence of Catalyst KOH. The Molar Ration for esterification of oil & Methanol for Cotton Seed oil is 4:1. The sequential process is presented in Figure 1. The various properties of diesel and Benola bio diesel are measured in the laboratory and presented in table 2 below. The viscosity, kinematic viscosity and flash point of Benola oil differ than pure diesel so pure Benola biodiesel can't be used in diesel engine. Only blended biodiesel can be used for internal combustion engines. The blending as per volume is filled in bottles and shown in Figure 2. The details of blending for B5 to B30 are explained in table 3.

Table 1. Measured Values of Physiochemical Properties

Properties	Diesel	Benola Biodiesel	ASTM 6751 standard	EN 14214 Standard
Density (gm/cm3)	0.82	0.88		0.86-0.9
Viscosity at 40°C	2.85	5.025		
Kinematic viscosity m2/s	2.8	4.6		3.5-5.0
Flash Point (°C)	6	182	Min. 130	Min 101
Fire Point (°C)	7	189		
Calorific Value	45.35	39.287		
Pour Point (°C)	-	-8		
Cloud Point (°C)	1	3		
Cetane no.	49	51	Min. 47	Min 51
Oxygen content	0	10.49		
HHV kJ/kg	42000	39500		

Table 2. Details of Different Blends

Sr. No.	Blends	Composition
1	B5	95% Diesel + 5% Biodiesel
2	B10	90% Diesel + 10% Biodiesel
3	B15	85% Diesel + 15% Biodiesel
4	B20	80% Diesel + 20% Biodiesel
5	B25	75% Diesel + 25% Biodiesel
6	B30	70% Diesel + 30% Biodiesel

Figure 2. Dampening of Benola methyl ester blending with diesel

2.2. Experimental Setup Specification and description

The specifications of the experimental engine are given in table 4.

Table 3. Engine Specifications

Particular	:	Specification
Engine	:	Four stroke single cylinder CI engine
Make	:	Prabhat
BHP	:	5 hp
RPM	:	1500
Fuel	:	Diesel
No. of cylinders	:	one
Bore	:	87.5 mm
Stroke length	:	110 mm
Starting	:	Manual cranking
Dynamometer	:	Brake Drum Type (Belt Type)
Drum Diameter	:	0.155 m
Max. Load Capacity	:	20kg
Coefficient of discharge	:	0.64
Working cycle	:	Four- stroke
Method of cooling	:	Water-cooling
Method of ignition	:	Compression ignition
Lubrication oil	:	SAE – 40 / equivalent

A Belt type brake drum dynamometer is used for applying the load on the engine. A digital speedometer is used to measure the shaft speed of the I. C. engine. Chromel – alumel thermocouples in conjunction with a digital temperature indicator are used for measuring the inlet and exhaust gas temperature. The experimental setup is shown in figure 3(a). The line diagram of set-up is shown in figure 3(b). In which 1-2-3-12 is air circuit. In this circuit air passed through air filter (2) and supplied to the engine through engine inlet valve. A U-tube manometer (4) is used for measurement of air supply to the engine. Air compressed by the piston in compression stroke at the end of compression combustion will starts and after completing the combustion in power stroke combust gases goes through the filter in the atmosphere and the sampling for emission has been taken before 12. The second circuit is 10-8-7-11-6 and is a fuel circuit for bio-diesel supply. Whereas 10 is a fuel tank, 9 is a graduated burette (transparent glass tube) which is used to measure the fuel consumption in engine per second, 8 is a fuel filter, 7 is a fuel pump and 6 is multi-point injector. For measuring brake power, a brake drum type dynamometer is used at the engine which shows in figure by 15 (drum) and 16 (belt and weight spring). Another most important circuit is the cooling circuit in which 14 is the source or sink of water supply to the engine where 13, 19, are the pump and three-way valve respectively. There are some tubes which play an important role in supply of air are 1 and 3, for fuel 11, for water 17 and 18.

Figure 3. (a) Photo of experimental setup

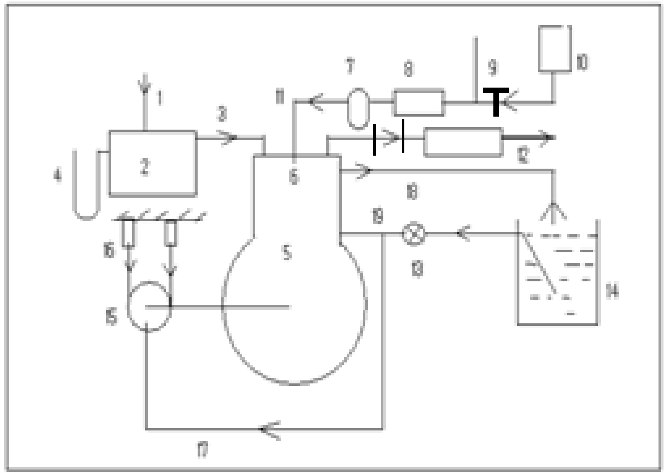

Figure 3. (b) Line diagram of IC engine circuit

2.3. Performance Evaluation

The Brake Power (bp), specific fuel consumption (sfc), thermal efficiency and mechanical efficiency (η_{mech}) have been calculated to determine the performance of the compression ignition engine based on Benola biodiesel as fuel by using the following equations. [30]

$$BP = \frac{2\pi NT}{60\times 1000}\ kW \quad (1)$$

Where Torque can be calculated by

$$T=(F1-F2)\times R_{eff} \quad (2)$$

The T is torque, N is revolution per minute (R.P.M.), F1 is the tension on the tight side and F2 is the tension on the slack side. The R_{eff} is the effective radius of the dynamometer (Drum radius +Belt Thickness),

The mass flow rate can be calculated by-

$$m = \rho v/t \quad (3)$$

Where, ρ is the density of fuel, v is the volume flow (Consumption of fuel in m^3) consumption within a certain time interval, t is the time interval for which consumption of fuel is to be measured.

The indicated power can be calculated by

$$IP=BP+FP \quad (4)$$

Where, IP is Indicated power, BP is brake power and FP is friction power. The friction power (FP) can be evaluated by Willian's line method.

The Mechanical efficiency can be evaluated by

$$\eta_{mech} = \frac{BP\times 100}{IP}\ \% \quad (5)$$

The brake thermal efficiency can be evaluated by-

$$\eta_{bth} = \frac{BP\times 3600\times 100}{M_f\times C.V}\ \% \quad (6)$$

The brake specific fuel consumption (BSFC) can be calculated by-

$$BSFC = (m_f.CV)/BP \tag{7}$$

The Brake mean effective pressure may be evaluated by-

$$BMEP = (BP \times 60 \times 1000)/LAN \tag{8}$$

Where, L is the stroke length (Swept length in the cylinder), A is the cross-section area of piston/cylinder and N is R.P.M.

3. Results and Discussion

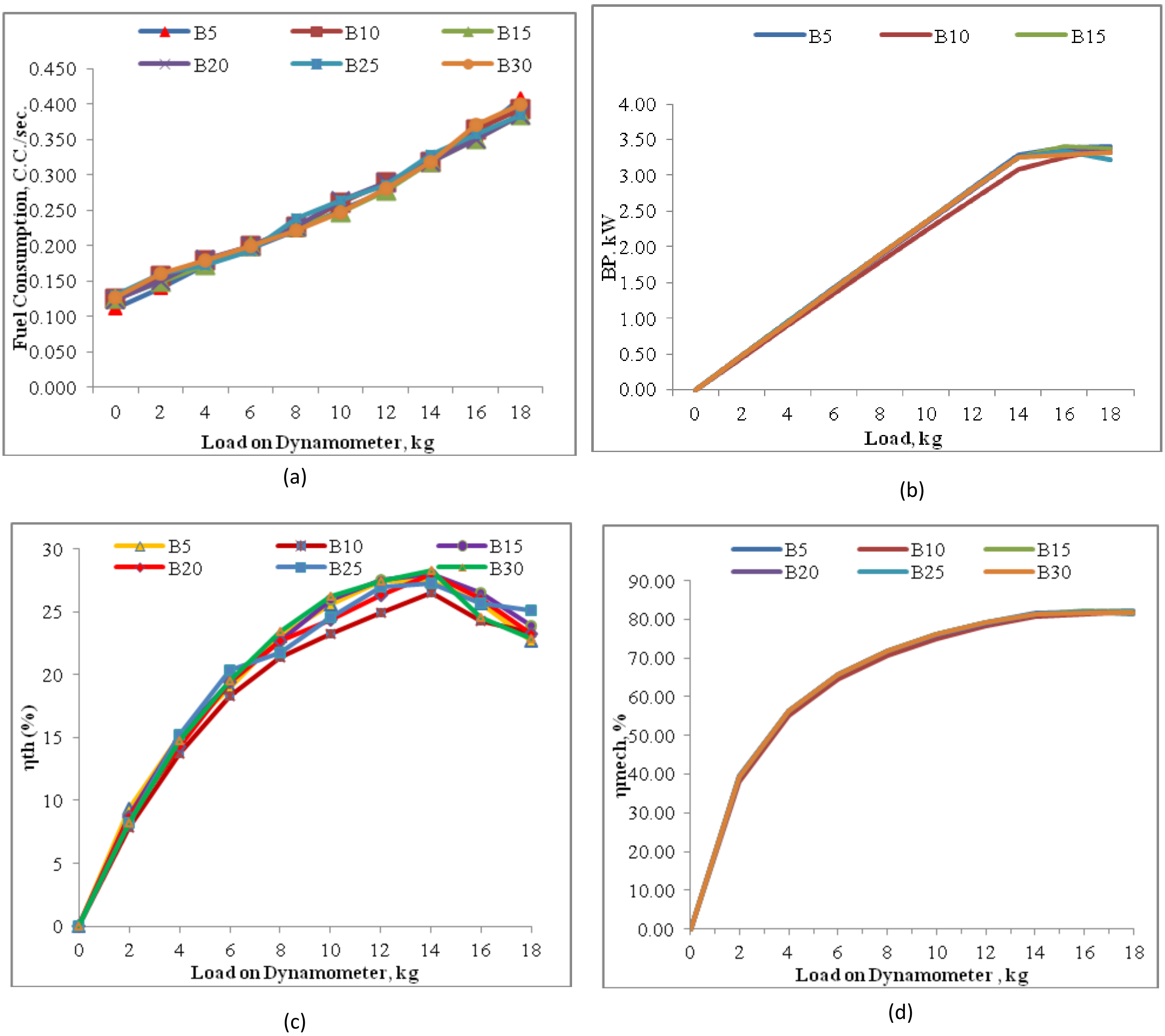

Figure 4. Performance Curves for Benola Biodiesel blended fueled 5 hp engine.

The performance characteristic curves for CI engine fueled with blended Benola biodiesel plotted for BP, Load, fuel consumption, brake thermal efficiency, mechanical efficiency as shown in figure 4. The engine performance is tested for various Benola biodiesel blends such as B0 to B30 and observed that the fuel consumption and brake power increases with increasing the load on dynamometer. The belt type dynamometer is used on the test set-up. The brake thermal efficiency is increases with increasing the load for all the blends, but it will be slightly reducing when increasing the blend more than 20% it means B20 is the optimum blend. The mechanical efficiency is also increasing with the increase in load but after some peak value it will be decreasing.

Some researchers also found that some changes are required for more % of blending because the vegetable oils (Benola oil) are more fatty acids than pure mineral diesel fuel.

4. Conclusions

The Benola seed oil blends performance offered close to diesel. Therefore, Benola seed oil can be used in CI engines in rural areas. The maximum limit of the blending is 30% but the most feasible blending is B20. It gives better performance like high break thermal efficiency and low specific fuel consumption as compared to the other blends. High power is also reported by many other researchers, and it may be due to better lubricity which reduces friction loss and better combustion of blends.

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