Optimized synthesis and physical properties of the biodiesel from fresh and waste vegetable oil

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Abstract— **The increase in the demand and prices of petroleum products as well as the environmental concerns resulting from the burning of fossil fuels in electricity production has resulted in focusing on the use of environmental friendly renewable alternative energy resources, like solar, hydro, tidal, wind, geothermal and biomass energy. There has been plenty of research done so far on engine performance and biodiesel production. Biodiesel was produced from fresh oil (BFO) and waste vegetable oil (BWO) on using biofuels for electricity generation. The engine performance tests were conducted with petroleum diesel and biodiesel samples at different loads and variable speeds. On comparing the electrical efficiency of generator and brake specific fuel consumption(BSFC) values, it was observed that less fuel is required for same power output when BFO (0.19kg/kWh) and BWO (0.18kg/kWh) were used in place of petroleum diesel. Moreover, an increase in BSFC values of BFO and BWO as compare to petroleum diesel at different speeds leads to the same interpretation. Higher efficiency and lower BSFC values of BFO (Efficiency: 43.25%; BSFC: 0.19 kg/kWhr) and BWO (Efficiency:41.34%;BSFC:0.2kg/kWh) due to complete combustion and reduction in calorific value of the fuel. In case of BWO, the operational efficiency (41.34%) was found less than the diesel-fueled condition.**

Keywords: biodiesel; engine; efficiency; brake specific fuel consumption;

I. INTRODUCTION

Two of the main contributors of the increasing energy demand have been the transportation and the basic industry sectors, being the largest energy consumers. The transport sector is utilizing petroleum fuels such as diesel, gasoline, liquefied petroleum gas (LPG) and compressed natural gas (CNG) 'on large scale [1]. Demand for transport fuels has risen significantly during the past few decades [2]. The demand for transport fuel has been increasing and expectations are that this trend will stay unchanged for the coming decades. In fact, with a worldwide increasing number of vehicles and a rising demand of emerging economies, demand will probably rise even harder. Transport fuel demand is traditionally satisfied by fossil fuel demand but resources of these fuels are running out, prices of fossil fuels are expected to rise and the combustion of fossil fuels has detrimental effects on the climate. Bio energy constitutes 15% of the world‘s energy consumption. Biofuels has fewer disadvantages as compared to other renewable energy resources. Resources for bio energy will not run out, they are becoming cost wise competitive with fossil fuels, they appear to be more environmental friendly and they are rather accessible to distribute and use as applicable infrastructure and technologies exists and are readily available The only drawback associated with bio energy is that some waste materials are not available all year round. Thus biofuels appear to be a best solution to substitute fossil fuels.

In dispersion through biomass energy sources, the importance of biodiesel is boosting as a substitute for diesel engines on account of oodles environmental qualities such as low greenhouse emissions [3]. Raw materials for the biodiesel production are unused oils, waste vegetable oils and animal fats. These raw materials are natural, renewable, biodegradable and nontoxic [4]. Biodiesel was produced by transesterification which reduces the viscosity of the oil so that it has properties closer to that of regular diesel used in CI engines. Biodiesel is outlined to have good lubricating properties for improving engine life and reduces engine component wear [5,6].The main parts of an electric generator are as follows: Engine, Alternator, Fuel System, Voltage Regulator, Cooling and Exhaust Systems, Lubrication System, Battery Charger, Control Panel, Main Assembly / Frame. Biodiesel is used as a fuel to provide mechanical energy as the input of a generator. The component of generator that is used to convert the chemical energy of the biodiesel into mechanical energy is named as engine. The working principle and energy extraction process that gives us a reasonable measure of energy extracted from the injected bio diesel is explained in detail. Diesel generators are generally single-cylinder diesel engine or multi-cylinder four-stroke diesel engines. The mechanical work produced for Single-cylinder four-stroke diesel engine completed in four strokes i.e. the intake stroke, compression stroke, combustion, and for the power (expansion) stroke and exhaust stroke. When the Pistons on the downward movement of the intake valve opens, the air filter filters fresh air into the cylinder to complete the intake stroke. Piston movement from the bottom up, into the exhaust valve are closed, the air is compressed, temperature and pressure increased, to complete the compression process. During the compression stroke, the air charge initially at atmospheric pressure and temperature is reduced in volume until the cylinder pressure is raised to between 30 and 50 bar. This compression of the air generates heat which will increase the charge temperature to at least 600 °C under normal running conditions [7]. Piston reaches the peak will be when the injector to the fuel through a filter to spray mist into the combustion chamber with high temperature and pressure of immediate self-ignition combustion air mixture to form a high-pressure push the piston down for power, push the crankshaft rotation, complete as power trip. Travel for work done, the piston moves from the bottom up, the exhaust valve opens the exhaust to complete the exhaust stroke. Half turn of each stroke crankshaft. The number of working cycles, diesel engines under the inertia of the flywheel gradually accelerates into the work.

Air standard diesel cycle is a formularized cycle for diesel engines. It is demonstrated on P-v diagram (Figure 1). In the Diesel Cycle analysis, only air is considered as the working fluid Ideal gas state equation is used –PV = RT.

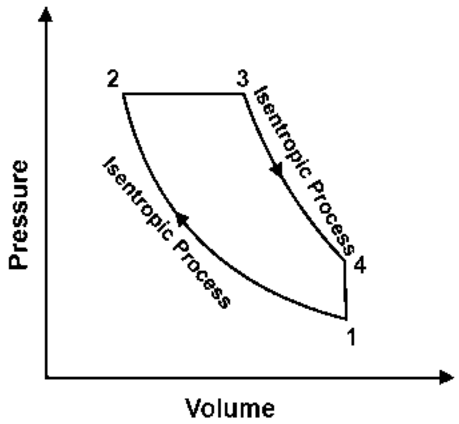

Figure 1.Diesel Cycle-P-V Diagram

The performance of an engine is calculated on the basis of the following [8]: Specific Fuel Consumption, Brake Mean Effective Pressure, Specific Power Output, and Specific Weight. The specific application of the engine chooses the relative importance of these performance parameters. There are few more parameters selected for engine evaluations are as follows: Power and Mechanical Efficiency, Mean Effective Pressure and Torque, Specific Output, Volumetric Efficiency, Fuel-air Ratio, Specific Fuel Consumption, Thermal Efficiency and Heat Balance, Exhaust Smoke and Other Emissions, Specific Weight.

II. METHODS

Biodiesel is produced from fresh and waste vegetable oil by transesterifation process. Transesterification is the process where an alcohol and an ester react to form a different alcohol and a different ester. For biodiesel, an ethyl ester chemically combines with methanol to form a methyl ester and ethanol. These ethyl esters react with methanol to produce biodiesel and glycerol.

The experiment was conducted on the generator operated at normal room temperature in the University of Management & Technology Lahore. This generator had worked for 276.2 hours before experiment. In our experiment, the generator was run at 1500 rpm continuously for 0.536 hours for BFO and 0.34 hours for BWO in order to achieve the thermal equilibrium.

Fresh, waste oil biodiesel and shell diesel were used for running the generator. Experimental setup was organized to calculate fuel consumption per unit time and the overall efficiency of the generator is called i.e. brake thermal efficiency. The amount of fuel consumed in an hour by the generator was determined by using diesel fuel consumption. The total electrical power load (brake power) consumed during an hour was measured by referencing the electrical output label on the generator. This could also be done by (1).The power equivalent of fuel is

$$P = m_f * C_v \quad (1)$$

Where,

m_f = fuel consumption rate in grams per second

C_v = LHV is the lower heating value of the fuel

In MEP [kPa], this becomes:

$$Fuel\,MEP = 2000 * \frac{PV}{N} \quad (2)$$

Where,

V = Engine displacement in liters

N = Engine speed (rps)

The output of the generator in kWh was divided by the input value of the fuel (power of fuel) used in kWh. Multiply this figure by 100 to express it as a percent.

$$\eta = \frac{E_{in}}{E_o} \quad (3)$$

Where,

η =Energy Efficiency

E_{in} = energy input in KWh

E_o = Energy output in KWh

The output of the generator could also be determines by the formula of brake thermal efficiency

TABLE 1.
ENGINE SPECIFICATIONS

Manufacturer	Cummins
Model	4B3.9-G2
Type	Single cylinder, 4 stroke, water cooled, vertical, compression ignition engine
Bore	102 mm
Stroke	120 mm
Rated Speed	1500 rpm
Rated Power	24 kW
Compression Ratio	18.2

III. RESULTS AND DISCUSSIONS

A. *Comparison of Fuel Efficiency*

Specific fuel usage and annual fuel consumption were estimated for biodiesel under study and compared with diesel Figure 2. shows the specific fuel consumption and fuel consumption for BFO and BWO. The specific fuel consumption of BFO and BWO under study was similar to shell diesel. Fuel Consumption of Shell diesel was 6L/hr at full load, higher than BFO and BWO. So BFO and BWO can be good quality fuels for running diesel generators as Fuel consumption is an important parameter for measuring fuel efficiency.

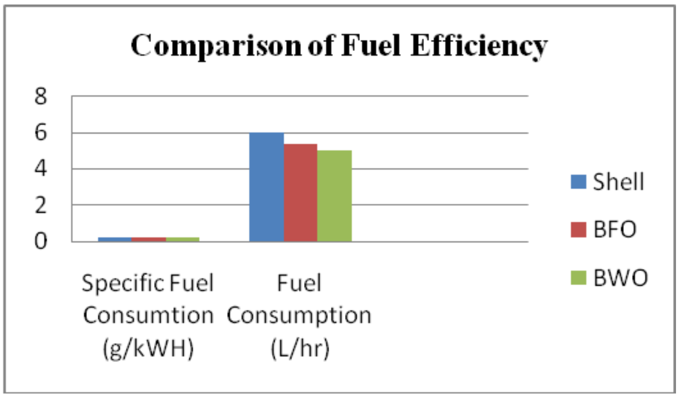

Figure 2: Comparison of fuel efficiency

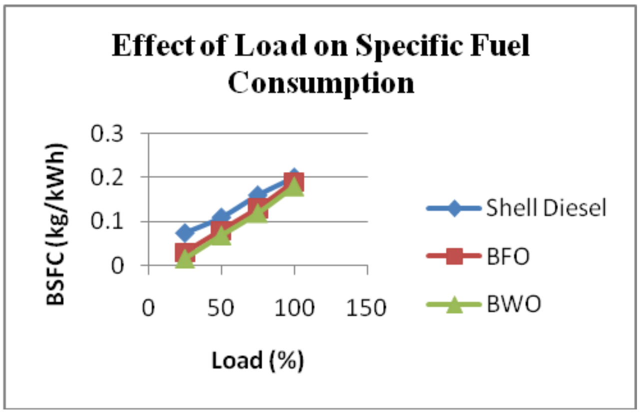

Figure 3. Effect of load on specific fuel consumption

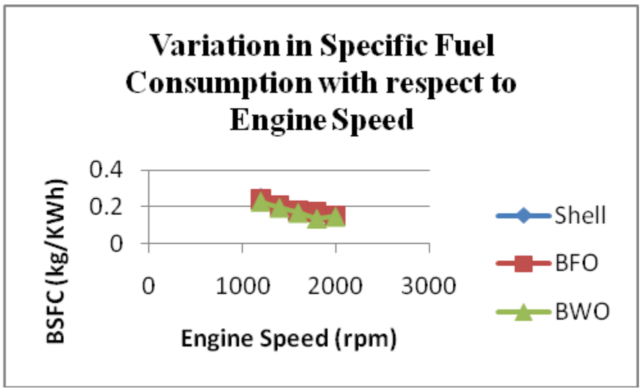

Figure 4. Variation in specific fuel consumption with respect to engine speed

B. *Effect of Load on Brake Specific Fuel Consumption*

The brake specific fuel consumption (BSFC) is estimated from the brake power output of the engine and the mass flow rate of the fuel. It is an important parameter to analyze the performance of the engine and fuel efficiency. The effect of load on BSFC for BFO and BWO compared to diesel fuel is shown in Figure 3. The BSFC values of the three samples resemble closely but that of BWO was lowest because of its low calorific value and, hence, less fuel is needed for the same power output. The BSFC values were 0.19, 0.18 and 0.200 kg/kWh for BFO, BWO and shell diesel respectively at 100% of rated load.

C. *Variation in Specific Fuel Consumption with Respect to Engine Speed*

In Figure 4, BSFCs of BFO and raw BWO are compared to shell diesel. While minimum BSFC with BFO and diesel fuel is obtained at 2000 rpm engine speed, it is obtained. The BSFC of all three fuels have resulted in almost overlapped curves. Using BFO and BWO methyl esters, an average increase of 13% and 14% was obtained with respect to Shell diesel. In the literature, increases in specific fuel consumption with the use of methyl ester have been reported. By using cottonseed methyl ester, [9] observed an increase within the interval of 8–10% in specific fuel consumption with respect to diesel fuel.

TABLE 2.

EFFICIENCY OF ELECTRICITY GENERATOR RUNNING ON DIFFERENT FUELS

Sr.No	Fuel Sample	Calorific Value(kJ/g)	Fuel Energy Input (Pf=LHVxFR) kWh	Energy Output (kWh)	Overall Efficiency
1	BFO	43,400	29.74	12.8614	43.25%
2	BWO	39,300	19.73	8.16	41.34%
3	Shell Diesel	45,000	27.21	9.8	36.00%

D. Comparative Efficiency Analysis

The value of overall efficiencies of electricity generator working on sample of biodiesel with shell diesel is presented in Table 2.

The overall efficiency of the 27.5 kVA electricity generator at full load fueled with samples of diesel was found in the range of 41-43% respectively as shown in Figure 5.4. In the case of BFO produced more power, and overall efficiency was found at maximum than diesel-fueled generator due to complete combustion and reduction in calorific value of the fuel. In case of BWO, the operational efficiency was found less than the diesel-fueled condition. During experimentation, it was observed that the engine ran very smoothly, without any noise and knocking when fueled with BFO. The engine was also run at constant revolution per minute in all the fuel samples.

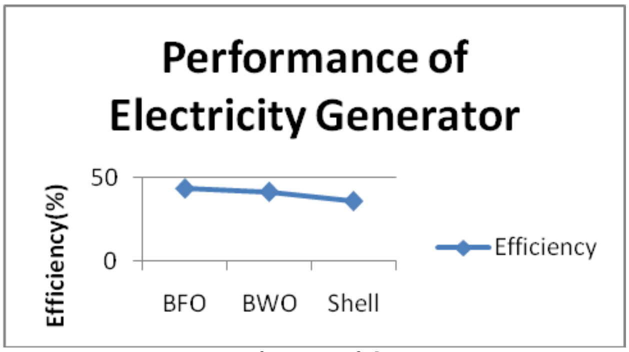

Figure 5. Performance of electricity generator

IV. CONCLUSIONS

Biodiesel was developed for the production of biodiesel from fresh and waste oil by using alkali catalyzed transesterification process. The performance tests were conducted with petroleum diesel and biodiesel samples at different loads and variable speeds. On comparing the electrical efficiency of generator and BSFC values, it was observed that less fuel is required for same power output when BFO and BWO were used in place of petroleum diesel. Moreover, an increase in BSFC values of BFO and BWO as compare to petroleum diesel at different speeds leads to the same interpretation. Higher efficiency and lower BSFC values of BFO and BWO due to complete combustion and reduction in calorific value of the fuel. In case of BWO, the operational efficiency was found less than the diesel-fueled condition. Biodiesel produced from waste oil is assessed to be feasible economical; however, for better quality of fuel, biodiesel from fresh oil (canola oil) is preferred to biodiesel produced from waste oil. Thus, biodiesel prepared from fresh as well as waste vegetable oil can be used as an alternate and nonconventional fuel to run diesel engine.

REFERENCES

[1] A. Demirbas, "Political, economic and environmental impacts of biofuels; A review," *Applied Energy.*, vol.86, no.1, pp. S 108–S117, April 2009.

[2] IEA (International Energy Agency) (2006), *World Energy Outlook 2008*, OECD/IEA,Paris.

[3] M.A. Dube, A.Y. Tremblay, and J. Liu, "Biodiesel production using a membrane reactor," *Biores. Technol.*, vol.98, no.3, pp. 639–647, Feburary 2007.

[4] J.M. Marchetti, V.U.Miguel, A.F. Errazu, "Possible methods for biodiesel production, *"Renewable and Sustainable Energy Reviews.*, vol. 11, no.6, pp.1300-1311, August 2007.

[5] A.K. Agarwal, B. Jayashree, and L.M. Das, "Effect of biodiesel utilization on wear of vital parts in compression ignition engine," *J. Eng. Gas. Turbine Power .*, vol. 125, no.2, pp. 604–611,2003.

[6] S. Sinha, A.K. Agarwal, and S. Garg, "Biodiesel development from rice bran oil: Transesterification process optimization and fuel characterization," *Energy Convers. Manage.* vol.49, no. 5 , pp.1248–1257, May 2008.

[7] http://www.firsthand.info/FourStrokeCycleCompressionIgnitionDieselEngine.html

[8] http://www.ignou.ac.in/upload/unit-7

[9] H. S. Yücesu, and C. Ilkılıç, "Effect of cotton seed oil methyl ester on the performance and exhaust emission of a diesel engine", *Energy Sources, Part A* vol.28, pp.389–398, 2006.