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Investigation of Neem Fatty Acid Ethyl Ester for Electric Power Generation

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Abstract

This paper presents biodiesel as an emerging renewable energy source which could meet substantially the very large growing electric energy demand maintaining the ecological balance. Biodiesel is a sustainable energy source which makes the environment out of pollution. The simplest process for biodiesel production called transesterification was carried out to produce biodiesel from neem oil. The output parameters such as speed, voltage, current and power are of the alternator are analysed for different loads using pure diesel, different biodiesel-diesel blends (80% biodiesel & 20% diesel, 60% biodiesel & 40% diesel, 40% biodiesel & 60% diesel, 20% biodiesel & 80% diesel) to an I.C engine. Results show that 20% biodiesel & 80% diesel blend (B_{20}) produces the output with better efficiency.

Keywords*: alternator performance, biodiesel, electrification, neem oil, transesterification*

1. Introduction

Energy has been a major factor in economic development of any country and one of the basic requirement of human life today. Present Indian energy scenario is met through fossil fuels and to a lesser extent by hydel, nuclear and renewable sources. But fossil sources are finite and inhomogeneously distributed, and their use normally creates polluted environment. To meet this challenge a globally responsible and rational energy policy encouraging the employment of effective strategies as well as adequate and already available instruments is required. Conventional resources are limited, non-renewable, polluting and, hence, their usage has to be prudent. Whereas, renewable energy sources are indigenous, non-polluting and virtually inexhaustible.

Renewable energy resources are abundant in India. With the increasing crude oil price around the world significantly, has reached more than $ 140 per barrel [1] which affects the economy of a country. Petroleum oil meets about 95% of the requirement for transportation. Demand for transportation fuel has increased and the electric energy demnd has also increased drastically due to technological inventions. Hence, biodiesel, a viable fuel for both transportation and electricity production has been discussed here. The country has a ray of hope in providing energy security using biofuels. They are environment friendly fuels and their utilization would address global concerns about containment of carbon emissions. Biofuels are derived from renewable bio-mass resources and, therefore, provide a strategic advantage of promoting sustainable development and supplementing conventional energy sources in meeting the rapidly increasing requirements for transportation fuels associated with high economic growth, as well as in meeting the energy needs of India's vast rural population. Developing countries also view biofuels as a potential means to stimulate rural development and create employment opportunities. It is based exclusively on non-food feed stocks to be raised on degraded or wastelands that are not suited to agriculture, thus avoiding a possible conflict of fuel vs food security.

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The average energy demand n India has grown up to 3.6% per annum over the past 30 years [2]. Coal reserves supports for India's major demand which accounts to 50% [3]. The various renewable sources and their potential in India as on march 2011 is shown in the Figure 1.

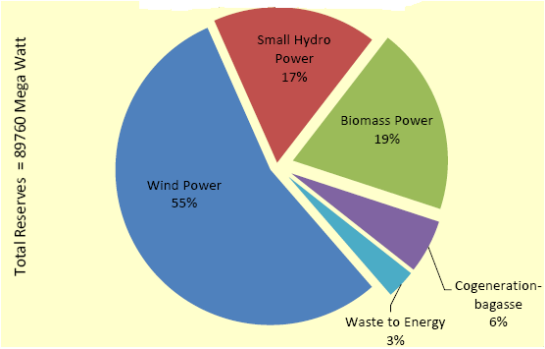


Figure 1. Renewable power potential in India

Some rural areas in India are unelectrified even with drastic change in technology. Solar energy, indeed, serves such areas. Wind energy too contributes to a small extent. upon Restriction is posed by climatic changes. Industries need more unswerving source of electric energy. In order to supply consistent energy, a source of energy which could be sought out is biodiesel which can be used in power generation for irrigation and electrification [4]. Bio-diesel is a source obtained from vegetable oils, animal fats and waste cooking oils. It is a tenable and self reliant fuel which reduces carbon and sulphur emissions [5]. Combustion of one liter of diesel fuel results in the emission of about 2.6 kilograms of CO_2. The properties of biodiesel are similar to that of petroleum diesel [6]. It can be used as a fuel to produce electricity [7, 8].

The overall electrification rate in India is 64.5% while 35.5% of the population still lives without access to electricity. Neem (Azadirachta Indica) is planted everywhere for purification of air, which could be used for biodiesel production now. These trees grow with well in bare lands. No extraordinary concern need to be taken for its growth. The seeds are of medicinal value, but not used 100%. The remaining seeds out of those used for medicine go waste. When these seeds are collected, crushed into oil and the oil used as the source of bio-diesel, the beneficiaries are the rural population [9]. Neem biodiesel could be used to run I.C engines and produce electricity [10].

2. Acid Composition in Neem Oil

Neem oil is available in India at minimum cost as India is one of the largest producer of neem oil. The amount of oil obtained from neem seeds is 30% [11]. Neem oil contains certain acids which are conscientious for burning of the oil. The amount of fatty acids present in the neem oil is the main reason for the conversion of bio-diesel from it. As the fatty acid content in it increases, the production of the bio-diesel decreases. The fatty acid contents of neem oil and their composition are listed in Table1. Neem oil has greater percentage of oleic acid in it. Therefore, the physical properties of oleic acid are listed in Table 2 [12]. The number of carbon atoms and the number of double bonds represented by m:n is different for different acids. The standard properties of diesel and biodiesel are shown in Table 3.

Table 1. Composition of Acids in Neem Oil Fatty Acids

Acid Name	Lipid Numbers	Composition Range
Linoleic acid	C18:2	2.3-15.8%
Oleic acid	C18:1	49-62%
Palmitic acid	C16:0	13.6-16.2%
Stearic acid	C18:0	14.4-24%
Alpha-linolenic acid	C14:0	0.2-2.6%

Table 2. Physical Characteristics of Oleic Acid

Physical Properties	Value
Boiling Point	286˚C
Density (d 20˚/4˚)	0.854
Melting Point	14.3˚C
Assay (GC)	65-88%
Acid Value	196-204
Iodine Value	87-95
Peroxide Value	10
Sulfated Ash (800˚C)	0.1%

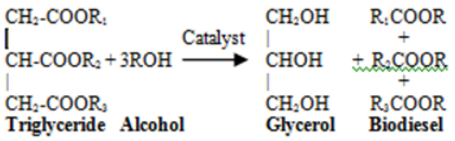
Table 3. Standard Properties of Diesel and Biodiesel

Properties	Diesel	Biodiesel
Flash Point (˚C)	55	120
Fire Point (˚C)	62	128
Density (Kg/m^3)	822	868
Calorific Values (MJ/Kg-K)	42.2	35.2%
Viscosity at 40°C (mm^2/s)	2.2	4.3

3. Biodiesel Production Method

Biodiesel, a renewable and sustainable fuel which is an alternative source to petroleum-based diesel. Two main methods by which biodiesel is produced are batch type and continuous type. Continuous type processors are generally large commercial machines capable of producing biodiesel in a continuous flow. Batch systems are commonly used method as they are simpler and cheaper to construct. In a batch system, all the necessary chemicals are mixed in a single vessel with a heater and mixing system and produce one batch at a time. Temperature plays a major role in the reaction because it affects the kinetic energy of the individual molecules. Transesterification is the simplest batch process which is used to produce biodiesel. Fatty esters, free fatty acids and some triglycerides are present in refined biodiesel [12]. Vegetable oils, animal fats and recycled grease are the sources of biodiesel. There are three ways by which esters are produces from oils and fats. a) Base catalyzed transesterification of the oil with alcohol, b) Direct acid catalyzed esterification of the oil with methanol, c) Conversion of the oil to fatty acids, and then to Alkyl esters [13].

The majority of the alkyl esters produced today are done with the base catalyzed reaction since it is the most economic for several reasons. a) Processing at low temperature and pressure, b) Conversion is possible with minimal side reactions and reaction time, c) No intermediate steps during conversion [13]. Parent oil used in making biodiesel consists of triglycerides in which three fatty acid molecules are esterified with a molecule of glycerol. Triglycerides react with a solvent (alcohol) in the presence of base catalysts (NaOH/KOH) known as transesterification to produce biodiesel. Base catalysts are preferred because of the fact that the transesterification reaction is generally faster, less expensive and more complete with these materials [14]. The stepwise reaction of biodiesel [15, 16] is shown in Equation (1).



(1)

Where R_1, R_2, & R_3 are long chain hydrocarbons. Three moles of alcohol are required stochiometrically for each mole of triglyceride to yield three moles of fatty acid ester and one mole of glycerol. In order to displace the equilibrium, a higher molar ratio is employed for getting greater ester production. Usual molar ratio is 1:6 [17, 18].

3.1. Transesterification Unit

Biodiesel production unit comprises of two units: the first unit is the container which is used for biodiesel production. It is a stainless steel container with six liters capacity and all the required devices/equipments within. Heater, thermocouple, stirrer with eight stainless steel

blades are the components present inside the container. In addition, this unit also contains a dc motor to operate the stirrer and a speed sensor on the top of the container. Operating speed of the stirrer is between 200 rpm to 900 rpm. The blades in the stirrer are placed at an angle of 45˚ and oriented at 45˚ to the base. The heater is of 1.5kW and is used to heat the oil. The temperature of the oil is sensed using Chromel Alumel (k-type) thermocouple. The container has an inlet valve at the top to let the raw oil, solvent and the catalyst and a valve at the bottom to drain the biodiesel and glycerol. The control unit is the second unit which is an electronic unit used to control the speed of the motor which in turn controls the speed of the stirrer and temperature of heater to control the oil temperature. The temperature of the oil can be varied from 30˚C to 250˚C. As this unit comprises of electronic components, cooling fan is provided for heat absorption. The transesterification kit is shown in Figure 2.

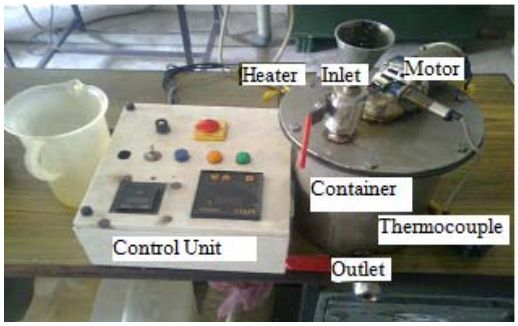


Figure 2. Transesterification Kit

4. Experimental Setup

The experimental setup for electric power generation is shown in Figure 3. Experiment has been conducted on neem oil with ethanol as solvent and KOH as catalyst. The final products obtained in this process are bio-diesel and glycerol. This entire process is called transesterification. The neem ester is used to run the I.C engine which is the prime mover for the 3Φ alternator. No modifications in the I.C engine are to be made for it to run using biodiesel. The engine used is Kirloskar diesel engine. The alternator and engine specifications are shown in Table 5 and 6 respectively. The equipment for emission measurement is shown in Figure 4.

Figure 3. Experimental Setup

Table 2. Alternator Specifications

KVA rating	5
No. of Phases	3
Speed	1500 RPM
Frequency	50 Hz
Voltage rating	230/450 V

Table 3. Engine Specifications

Horse power	5
Power rating	3.7kW diesel engine
Engine orientation	Vertical
No. of cylinders	1
No. of strokes	4

Figure 4. Emission Measuring Equipment

4.1. Biodiesel Preparation Procedure [19]

Neem oil is pretreated to remove excess FFA and moisture content from it. This partially purified neem oil is heated to a temperature of 75˚C/65˚C, the temperatures being the boiling point of ethanol/methanol (solvent) under agitation in order to produce ethyl ester/ methyl ester. The catalyst as required is weighed promptly to avoid the reaction with the atmospheric moisture and carbon di-oxide.The catalyst and the solvent solution are shaken vigorously in a conical flask for homogeneous mixing. The dissolved catalyst is presumed to have been converted into potassium/sodium alkoxide. Weighed quantity of the homogeneous solution is added to the oil to mark up the start of reaction. Heating and stirring are stopped once the preset reaction time is reached. The obtained product is allowed to settle overnight. Two liquid phases are identified with esters being dense goes to the top and glycerol settles at the bottom.Crude ester is separated and glycerol is washed by warm double distilled water four times. The excess alcohol and water in the ester phase is removed by evaporation under atmospheric condition.

5. Results and Discussion

The I.C engine was run with pure diesel and various blends of diesel and biodiesel to analyse the performance of the alternator. When biodiesel is pure biodiesel, it is called B_{100}. The mixture of 20% biodiesel and 80% diesel is called B_{20} [21]. The output parameters such as speed, voltage, current and power are of the alternator are analysed for different loads using pure diesel, different biodiesel-diesel blends (80% biodiesel & 20% diesel, 60% biodiesel & 40% diesel, 40% biodiesel & 60% diesel, 20% biodiesel & 80% diesel) to an I.C engine. The speed, voltage, current and frequency variation of the alternator with increase in load were observed. The relationship between speed and voltage, speed and current, speed and

frequency, speed and power, speed and efficiency are shown in Figure 5 to Figure 9 respectively. Speed, voltage and frequency reduces with increase in load, current, power and efficiency increases with increase in load. Results show that 20% biodiesel & 80% diesel blend (B_{20}) produces the output with better efficiency. Emission profile of diesel and bio-diesel is shown in Figure 10. It shows that NO_x gas emission is more and all other emissions are considerably less for neem biodiesel compared with petroleum diesel.

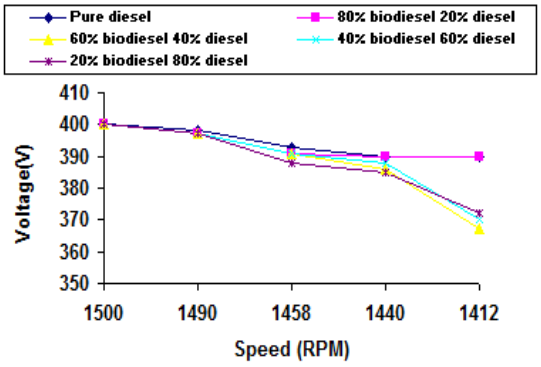


Figure 5. Speed vs Voltage Characteristics of Alternator

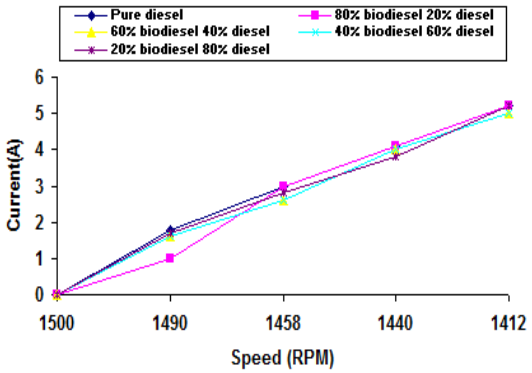


Figure 6. Speed vs Current Characteristics of Alternator

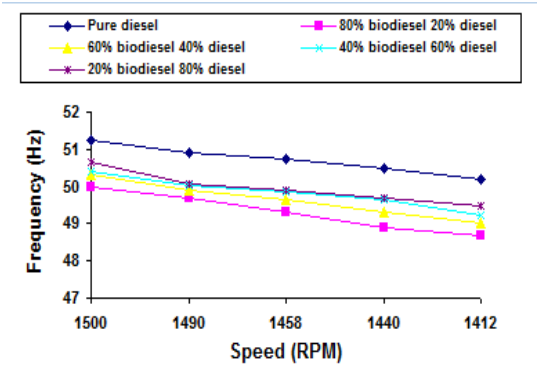


Figure 7. Speed vs Frequency Characteristics of Alternator

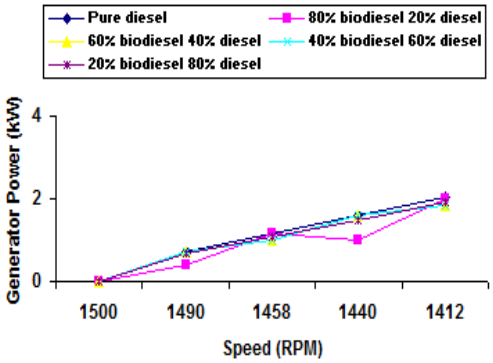


Figure 8. Speed vs Generator Power Characteristics

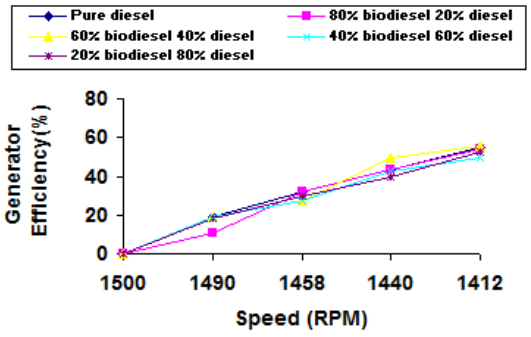


Figure 9. Speed vs Generator Efficiency Characteristics

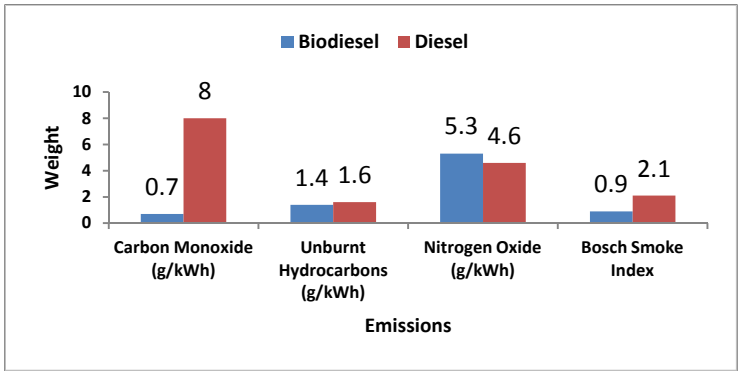


Figure 10. Biodiesel and Diesel Emission Profile

6. Conclusion

This study shows that the neem biodiesel could be produced at minimal cost and be used as a viable alternative. The esterification process output depends on the proportion of the added solvent and catalyst to the oil and the reaction temperature for the required time. The speed, voltage, current, frequency, power and efficiency of the alternator obtained for various blends (80% biodiesel & 20% diesel, 60% biodiesel & 40% diesel, 40% biodiesel & 60% diesel, 20% biodiesel & 80% diesel) and various loads proves that biodiesel could be a reliable alternative fuel for electricity generation and lights the lfe of rural population. Also, the analysis shows that B_{20} produces better results when compared with other blends. The emissions except NO_x is found to be reduced compared to diesel fuel creating less polluted environment.

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