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EXPERIMENTAL INVESTIGATION ON JATROPHA OIL AS A BIODIESEL FUEL WITH ANALYSIS OF ITS EMISSION CHARACTERISTICS

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ABSTRACT: The scarcity of fuel and daily increasing price of fuel has become a cornerstone in the development of many countries. Developing in the industrial sector and growing population has increased the demand for energy globally in recent years. Also the increasing pollution due to large number of automobiles has become an important consideration. To overcome all these problems, there is a need of an economic alternative fuel which would be a replacement over current fuels, providing energy without creating any pollution. So in order to meet the current demands and to fulfil the requirements of energy jatropha oil can be a good choice as a biodiesel for diesel engines. Experimental results have shown it as a significant environmental and economically beneficial fuel. Jatropha oil obtained has higher specific gravity, carbon residue, cetane number, lesser sulphur content and lesser pour point compared to standard diesel with almost same calorific value. Jatropha produces seeds which contains 30-40% oil. All these qualities make it a good replacement for standard diesel. It is an alternative fuel and provides a domestic renewable energy supply [1]. The objective of this paper is to update the production of biodiesel from jatropha seeds and research attempts to improve technology used for converting seed oil to biodiesel to reduce the pollution level.

Keywords- Jatropha; transesterification process; biodiesel esterification; saponification; emission characteristics.

1. INTRODUCTION

Now days, a major research is focussed on the sustainable energy solutions with major emphasis on the energy efficiency and use of renewable energy resources. Increasing pollution and diminishing petroleum reserves are the driving forces to promote the use of biodiesel as an alternative fuel. This fuel is accepted worldwide and is acting as a great solution over the environmental problems. A large variety of alternatives fuels have been suggested as a substitute by the researchers and scientists but modification, handling, transportation and the ease of production are some of the major components which needs to be considered while selecting a new alternative. The main reason for this research for the alternative fuel is the increasing prices of the available fuels which have been seen reaching too sky high. As oil has always been the major source of energy its sources are vanishing. Current use of the renewable energy sources accounts merely 13% over the worlds primary energy demand.

Still 80-90% requirements of energies are fulfilled by fossil fuels only. To reduce this dependence on the petroleum fuels for better environment and economy, it is evident to make use of the available alternative fuels. Some of the most promising liquid fuels in current use in the market are ethanol, methanol, vegetables oil and biodiesel. But amongst all these biodiesel is considered as the most promising substitute over the current fuels because of its renewable nature and environmental friendliness. Basically biodiesel is considered as a substitute over the diesel oil and can be produced from a chemical process known as ‘transesterification’. Transesterification is a chemical process in which the vegetable oil or animal fat reacts with an alcohol such as methanol. The reaction requires a catalyst, usually a strong acid such as sodium or potassium hydroxide and produces new chemical compounds known as methyl esters. It is these esters which further came to be known as biodiesel. Depending upon the availability and production capabilities, biodiesel can be produced from number of oilseeds. In India, biodiesel can be produced from a wild plant jatropha curcas, which can grow in arid, semiarid and wastelands. It requires less water and fertilizers and can survive on infertile soils and the most important factor is it is not grazed by cattle’s. Hence its production is safe. Jatropha oil is a promising alternative as it is renewable, environmental friendly and easily produced in rural areas, where, there is an acute need for modern forms of energy. Thus jatropha ensures reasonable production of seeds with very less inputs. Also systematic efforts have been made by several research workers to use vegetable oil as fuel in engines [4]. Seeing the cost and edible oil consumption, the use of non-edible oils is more significant. Practically Jatropha tree or shrubs grows all over India under almost all the climatic conditions and it is commonly found in most of the tropical and subtropical areas of the world [4]. The proximate analysis of jatropha seeds revealed that the percentage of crude protein, crude fat and moisture were 24.60, 47.25 and 5.54% respectively [2]. It is also pest resistant and has high seed yielding capacity which promotes its production business over wide scale. The seeds can be transported without deterioration and at low cost due to its low specific weight. Some other factors which influence its use are its ability to produce oil seeds on large scale and the oil content. On an average, it can produce oil seeds up to 30-40 years and the oil content in the seeds is around 30-40%. In India, more than 90 million hectares of land exists and if such huge area comes under the cover of jatropha, the scarcity of the petroleum based fuels will ultimately come to an end [1]. It will also provide a green cover over the wastelands, support to agricultural and rural economy and will help to reduce air pollution. The processed oil can be directly used in diesel engines after minor modifications or it can be used after blending with conventional diesel. The fact that the oil of jatropha curcas cannot be used for nutritional purposes without detoxification makes its use as an energy source for fuel production very attractive. The by-products of the diesel processing plant are nitrogen-rich press cake and glycerol, which are said to have good commercial qualities as fertilizers and as a base for the production of soap and cosmetics, respectively.

BIODIESEL BLENDS

Biodiesel can be used directly in its pure form i.e. 100% biodiesel fuel. It is referred as B100 or "neat fuel". Biodiesel contains no petroleum but it can be blended any level with the petroleum diesel to create biodiesel blend. A biodiesel blend is pure biodiesel blended with petro diesel [1]. It can be used in the compression ignition engines with some little or no modifications. These fuels are technically feasible, economically competitive, environmentally acceptable and easily available. It improves emission levels of some of pollutants and deteriorates other. 100% biodiesel fuel i.e. biodiesel is monoalkyl esters of vegetables oil or animal fats. The vegetable oils and fats which are also considered as a alternative fuel for engines are all extremely viscous with viscosities ranging from 10 to 17 times greater than petroleum diesel fuel. So, biodiesel is generally produced by transesterification to parent oil or fat to achieve a viscosity close to that of the petro diesel oil. The chemical conversion of the oil to its corresponding fatty ester is called transesterification. Its main purpose is reduction of viscosity of the resulting bio-fuel. The transesterification reaction proceeds with catalyst or without catalyst by using primary or secondary monohydric aliphatic alcohols having 1-4 carbon atoms.

Triglycerides + Monohydric alcohol → Glycerine + Monoalkyls (biodiesel)

TRANSESTERIFICATION REACTION

CHEMICAL COMPOSITION AND SPECIFICATION

Fig.1.JATROPHA SEEDS

The Jatropha curcas is a plant that is generally cultivated for the purpose of extracting jatropha oil. The seeds are the primary sources from which the oil is extracted. Because of its toxicity, they are not used by humans. Therefore, the major goal of the jatropha cultivation is extracting jatropha oil.

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Analysis of jatropha curcas seed shows the following chemical compositions-

Moisture: 6.20%

Protein: 18%

Fat: 38%

Carbohydrates: 17%

Fibre: 15.50%

Ash: 5.30%

Fig.2.JATROPHA OIL

The oil content in the seeds is in the range of 30-40%. The oil contains 21% saturated fatty acids and 79% unsaturated fatty acids [3]. These are some of the chemical elements in the seed, cursin, which poisonous and render the oil not appropriate for human consumption.

Oil has very high saponification value and being extensively used by various industries for making soap. Also this oil is used as an illuminate in lamps as it burns without emitting smoke. Along with all these it is being extensively used as a fuel in place of or with kerosene stoves. Oil cake obtained from cake is rich in nitrogen, phosphorus, potassium and can be used as organic manure. By a thermodynamic conversion process, pyrolysis, useful products can be obtained from jatropha oil cake. The obtained products are in the form of solid, liquid and gaseous form. The liquid can be used as a fuel in furnace and boiler. It can be upgraded to a higher grade fuel by the process of transesterification [3]. In simple words it can be easily concluded that, the non edible oil obtained from the jatropha curcas has the requisite potential providing a promising and commercially viable alternative to diesel oil as it has the entire desirable qualities, physical, chemical and performance characteristics comparable to diesel oil. Vehicles could be run with jatropha curcas without requiring much change in the design of the engine in current use. Jatropha oil is basically extracted from seeds and filtered through filter process can replace kerosene or lamp oil. Jatropha oil can be effectively used as a fuel for lightning as well as cooking purposes too. It will also be useful in big diesel engines for electricity generating sets, pump sets, heavy farm machineries, where the viscosity of oil is not a big issue. The seeds of jatropha contain viscous oil i.e. 50% by weight, which can be used for manufacturing of candles and soaps, in the chemical industry, for cooking and lightning by itself or as a diesel/paraffin substitute or extender. The later use has important implications for meeting the demands for rural energy services and also exploring practical substitute for fossil fuels to counter green house gas accumulation in the atmosphere.

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2. METHODS AND DEVICES FOR EXTRACTION OF JATROPHA OIL

OIL EXTRACTION

Oil extraction may be done:

Mechanically by pressing the kernels

Chemically

Enzymatically

Some common methods available for extraction of the jatropha oil are as follows:-

OIL PRESSES

These are the common mechanical devices generally used for the extraction of jatropha oil. These are either powered or manual driven. Among all the available mechanical presses available for this operation the most commonly used is Bielenberg ram press. The Bielenberg ram press involves the traditional press method to extract oil and prepares oil cakes as well as soaps. It is a simple device that yields around 3litres of oil per 12 kg of seed input. As jatropha oil is the most important factor needed for production of jathropha biodiesel the extraction methods and the optimization of existing methods of extracting the oil have become significant.

OIL EXPELLERS

Various types of oil expellers are available. The most commonly use amongst all those is Sayari oil expeller also known as Sundhara oil expellers and the Komet expeller. The Sayari expeller is a diesel operated device developed in Nepal. It is now being developed for use in Tanzania and Zimbabwe for the purpose of jatropha oil extraction and oil cake preparation. The model working on electricity is also available. The Komet expeller is a single screw oil expeller that is often used for extracting jatropha oil from the seeds and also for the preparation of oil cakes.

MODERN CONCEPTS

Methods like ultrasonication have been discovered to e effective in increasing the percentage of jatropha oil that can be extracted using chemical methods like aques enzymatic treatment. The optimum yield for such methods has been discovered to be around 75%. Jatropha oil extraction methods are still being researched. The goal of such researches is to discover methods to extract a greater percentage of jatropha oil from the seeds than the current procedures allow [3].

3.EXPERIMENTAL SETUP

The reactor used for experiments was a 1000ml three necked round bottom flask. The flask is placed on a water bath. The centre neck is fitted with a stirrer. One of the two side necks is equipped with a condenser and the other is used for thermo-well and for sample collection. A thermometer is placed in the thermo-well for temperature measurement inside the reactor. The motor is connected to a speed regulator for adjusting and controlling the stirrer speed.

ESTERIFICATION

A known amount of jatropha oil is taken into the three necked round bottom flask. Heating mantle is used for the supply of heat. A known amount of sulphuric acid in methanol is added to oil and continuously stirred maintaining the steady temperature of 65 °C. Reaction is continued for two hours. Under optimal condition esterification is performed using acid catalyst (5% H_2SO_4) and methanol (20% of oil). Intermittently samples are collected at regular intervals (30 minutes) and acid values are determined. Esterification is continued till the acid value reduced to <1. The excess methanol from the reaction is out and total mass further dried under vacuum to remove the moisture present in the oil samples. The organic layer after neutralizing with

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10% NaOH solution the reaction temperature is maintained at 65°C for 25 minutes. The refined sample is further cooled and centrifuged to remove residual soap. The oil after esterification undergoes transesterification to obtain methyl esters.

TRANSESTERIFICATION

In a typical experiment a known amount of jatropha oil is charged to a round bottom flask. A known amount of catalyst (NaOH) based on weight percent of oil is mixed in excess mole percent of methanol. The mixture of sodium hydroxide in methanol is added to the jatropha oil in the round bottom flask, while stirring the material of the flask. Required temperature is maintained by controlling the electrical heating till the reaction is completed. After complete addition of methanol-NaOH-solution samples are drawn at regular interval (5-10 minutes) to confirm the formation of methyl ester. The formation of methyl ester is checked by using thin layer chromatography (TLC) technique.

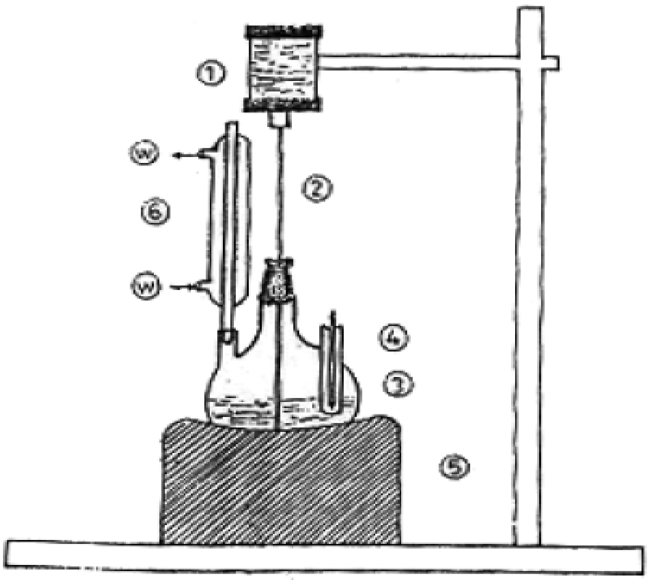

Fig.4.EXPERIMENTAL SETUP FOR PREPARATION OF METHYL ESTER FROM JATROPHA OIL

1 ELECTRIC MOTOR

2 STIRRER

3 THREE NECKED ROUND BOTTOM FLASK

4 THERMO-WELL WITH THERMOMETER

5 WATER BATH

6 CONDENSER

After the completion of methyl ester formation, a known amount of sulphuric acid in methanol is added to the methyl ester to neutralize the sodium hydroxide present in the ester. The excess methanol present in the methyl ester is recovered by distillation with electrical heating and constant stirring. A sample of jatropha oil methyl ester is analysed for acid value and then refined with NaOH solution to remove the free fatty acids. The transesterification reaction temperature is maintained at 65 °C for two hours keeping the molar ratio of methanol to oil at 6:1 and sodium hydroxide concentration of 0.7 weight percentage of

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oil and percentage of excess methanol used is 200%. The refined sample is further cooled and centrifuged to remove residual soap. The pH level of organic layers is measured and neutralized separately. The washed samples were further dried. Under optimal conditions the yield of jatropha oil methyl ester from jatropha oil is about 97%. The reaction parameter such as methanol/oil molar ratio, % of excess alcohol, reaction time and temperature, concentration of catalyst are optimized for the production of jatropha oil methyl ester. Various fuel properties of jatropha oils and jatropha oil methyl esters are determined experimentally to ascertain their suitability as diesel fuel [4].

Fig.4.DURING BIODIESEL PRODUCTION

3. IMPORTANCE OF JATROPHA CURCAS AS AN ENERGY SOURCE

Number of variety of jatropha is available but amongst all those jatropha curcas is best suitable. Jatropha oil is the important product from the plant for meeting the cooking and lightning needs of the rural population, boiler fuel for industrial purpose or as a viable substitute for diesel. About one third of the energy in the fruit of jatropha can be extracted as oil that has a similar properties and energy value as that of diesel oil. Jatropha oil can be directly used in diesel engines added to diesel fuel as an extender or transesterified to biodiesel fuel. Some modifications needs to done in design of diesel engine for direct use of jatropha biofuel.

Fig.5.JATROPHA PLANT

Table 1.Comparison of experimental and theoretical values of different properties of vegetable oil.

Vegetable oil	Experimental	Theoretical	Experimental	Theoretical	Experimental	Theoretical

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	saponification value	saponification value	iodine value	iodine value	acid value	acid value
Palm oil	105-110	106.45	97	95	190-210	218
Rapeseed oil	315.2	298.45	94.2	98	180-210	215
Linseed oil	189-195	188.12	165-205	170	197-204	181
Jatropha oil	196-200	199.24	96-105	101	5.31	8
Karanja oil	186-196	190	80-90	96	20	24
Mahua oil	190-195	191	60-65	63	18.38	27

Table 2. Comparison fuel properties of Jattopha oil, Jatropha oil methyl ester and Diesel oil.

Roperty	Unit	Jatropha oil	Jatropha oil methyl ester	Diesel	ASTM D 6751-02	DIN EN-14214
Density at 15˚C	Kg/m^3	918	880	805	875-900	860-900
Viscosity at 40˚C	Mm^2/s	35.4	4.84	2.60	1.9-6.0	3.5-5.0
Flash point	˚C	186	162	70	>130	>120
Pour point	˚C	-6	-6	-20	-	-
Water content	%	5	Nil	0.02	<0.03	<0.05
Ash content	%	0.7	Nil	0.01	<0.02	<0.02
Carbon residue	%	0.3	0.025	0.17	-	<0.3
Sulphur content	%	0.02	Nil	-	0.05	-
Acid value	Mg KOH/g	11.0	0.24	0.35	<0.8	<0.50
Iodine value	-	101	104	-	-	-
Saponication value	-	194	190	-	-	-
Calorific value	MJ/kg	33	37.2	42	-	-
Cetane number	-	23	51.6	46	-	-

5. APPLICATION OF BIODIESEL IN COMBUSTION ENGINES

The properties of jatropha oil, jatropha biodiesel and fossil diesel are compared in the above table [2]. The high viscosity of the vegetable oils leads to various problems in case of pumping and spray characteristics when used in diesel engines. The best to use the vegetable oil as fuel in compression ignition engines is to convert it into biodiesel. Biodiesel can be blended in various proportions with fossil diesel to create a biodiesel blend or can be used in its pure form. It can be used in compression ignition engines with very little or no modifications because it has properties similar to mineral diesel. Jatropha bio fuel offers almost same power as that of diesel fuel. In addition with that it controls the emission level i.e. in comparison with diesel, its emission is less. Hence it is better in environmental effects are considered.

ADVANTAGES OF BIODIESEL

1. Provides a domestic, renewable energy supply.
2. Biodiesel is carbon neutral because the balance between the amount of CO2 emissions and the amount of CO2 absorbed by the plants producing vegetable oil is equal.
3. Biodiesel can be used directly in compression ignition engines with no substantial modifications of the engine.
4. Blending of biodiesel with diesel fuel increases engine efficiency.
5. The higher flash point of biodiesel makes its storage safer.
6. Biodiesel is non-toxic.
7. Biodiesel degrades four times faster than diesel.
8. CO, CO@ and UBHC, PAH, soot and aromatics emissions are reduced in biodiesel and its blends than in fossil diesel because biodiesel is oxygen in structure and it burns clearly all the fuels.

9. It is biodegradable.

EFFECTS OF BIODIESEL ON EMISSION

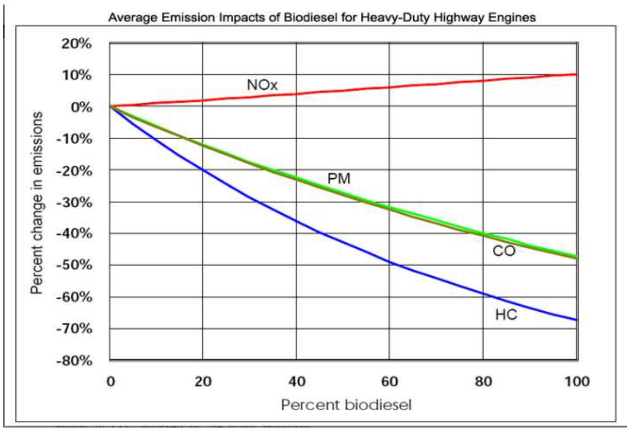

Fig.6.EFFECTS OF JATROPHA BIODIESEL ON CO2, CO, HC AND NOx EMISSIONS FOR HEAVY DUTY VEHICLES

- Reduces HC (Hydrocarbon) emissions.
- Reduces CO2 emissions as well CO emissions as it always supports the complete combustion of fuel.
- Reduces the chances of smoke after burning.
- It increases the NOx level if used in case of heavy duty vehicles but if considered in case of small vehicles/cars NOx emission level is not greater than that due to fossil diesel fuel.

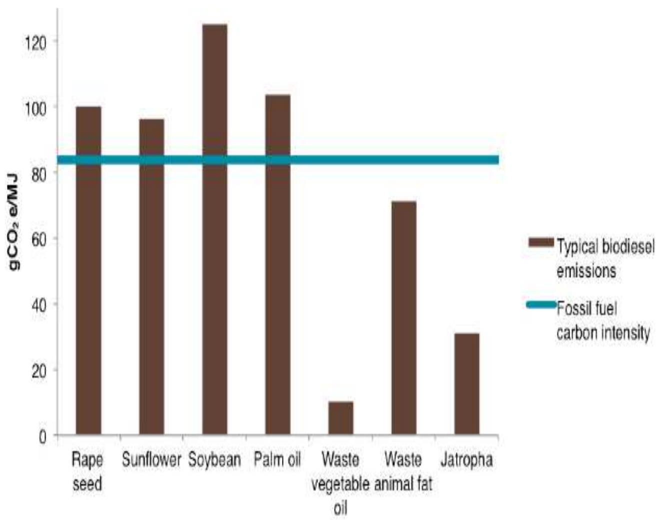

Fig.7. COMPARISON OF CO2 EMISSION BY BIODIESEL AND DIESEL

6. CONCLUSION

The results shown by the graphs are concluded on the basis of application of biodiesel on the diesel engine. The major advantage of this alternative fuel is its environmental friendly nature. Data plotted on the graphs clearly shoes that Jatropha oil can serve as an excellent alternative fuel. The jatropha oil was characterized on the basis of its viscosity, density, cetane number, cloud and pour point, characteristics of distillation, flash and combustion points. Biodiesel from Jatropha oil is easy to handle because of its volatile nature. There is always a danger of accidental burning/ignition in case of the liquid fuels while it is being stored transported or transferred from one place to another. The chances of having such accidents while storage also depends on the temperature at which it is stored as its ignition is related to temperature at which the fuel will create enough vapours to ignite, known as the flash point temperature. For example, the flash point of the gasoline fuel is -40 °F, which means it can burn at the temperatures as low as -40 °F. Jatropha biodiesel on other hand is safer to handle in these cases as it is having a flash point of over 266 °F, which means it cannot burn until it is heated at the temperature above the boiling point of the water. Cylinder pressure characterizes the ability of the fuel to mix well with air and burn. High peak pressure and maximum rate of pressure rise corresponds to large amount of fuel burnt in premixed combustion stage. It may be due to higher cetane index of Jatropha biodiesel resulting into shorter ignition delay and more fuel burnt in the diffusion stage. Also as compared in case of the emission point of view it is again best suited for the substitute over the fossil diesel oil. So in all the parameters biodiesel can be a better option for diesel engines in current use. It will also evolve new technologies regarding the new engine design and other engine parts which are related to the combustion of fuel inside the engine.

So to overcome the problems of current fuel scarcity and rapid increase in the prices of the fuels and the most important factor which the human facing now a day i.e. pollution due to large number of vehicles, it is necessary to make use of such a alternative fuel like jatropha oil. In case of comparison with the diesel engine performance and emissions, biodiesel from jatropha oil and its blends can be used in these available diesel engines without any modifications which are the major advantage of its use. In short Jatropha biodiesel improves the life of diesel engine, can be used as a fuel lubricity addictive in diesel fuel, results in drop in fuel economy, is an alternative fuel and provides a domestic renewable energy supply.

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