Experimental Investigation of a 4 Stroke CI Engine Using Coconut Biodiesel and Its Blends

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Abstract- Diesel and other petroleum products being non-renewable sources of energy are fast depleting. According to scientific analysis petro products will be completely deplete in next 20-30 years. Hence research work is on to find alternative fuels to fuel our vehicles. Many alternative fuels have been found and experiments are being done to put them to use in place of present fuels. The problem with those alternative fuels like using electricity to run our automobiles results in a complete makeover of automobile models rendering the old ones useless. Hence we need such alternative and replenish able resources that do not require any major modifications done to the automobile design, mainly engine design. One such fuel is coconut oil bio-diesel which has excellent properties compared to other bio-diesels and has properties very near to those of ordinary diesel. So no modifications are necessary in the engine design. It has very less exhaust emissions compared to other biodiesels and even diesel making it the most environment friendly fuel. In this paper we have conducted experiments to chart out bio-diesel properties and compared them with those of neat diesel by preparing our own coconut bio-diesel and went to conduct load tests with 100% bio-diesel (also called B100) and also blend B80, B60, B40 and B20 and compared this with results with those done with neat diesel.

Keywords – Alternative fuels, Bio-diesel, Coconut oil, diesel blends, engine performance.

I. INTRODUCTION

Biodiesel refers to a non-petroleum-based diesel fuel consisting of long chain alkyl (methyl, propyl orethyl) esters, made by transesterification of vegetable oil or animal fat (tallow), which can be used (alone, or blended with conventional petro-diesel) in unmodified diesel-engine vehicles.

A. BLENDS

Blends of biodiesel and conventional hydrocarbon-based diesel are products most commonly distributed for use in the retail diesel fuel marketplace. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix: fuel containing 20% biodiesel is labeled B20; while pure biodiesel is referred to as B100.Blends of 20 percent biodiesel with 80 percent petroleum diesel (B20) can generally be used in unmodified diesel engines. Biodiesel can also be used in its pure form (B100), but may require certain engine modifications to avoid maintenance and performance problems.

Biodiesel can be used in pure form (B100) or may be blended with petroleum diesel at any concentration in most modern diesel engines. Biodiesel has different solvent properties than petro diesel, and will degrade natural rubber gaskets and hoses in vehicles (mostly vehicles manufactured before 1992), although these tend to wear out naturally and most likely will have already been replaced with FKM, which is nonreactive to biodiesel. Biodiesel has been known to break down deposits of residue in the fuel lines where petro diesel has been used. As a result, fuel filters may become clogged with particulates if a quick transition to pure biodiesel is made. Therefore, it is recommended to change the fuel filters on engines and heaters shortly after first switching to a biodiesel blend.

But anyway the engine runs uninterrupted even without any modifications with B100.The modifications maybe necessary only to avoid any damage that might be caused due to prolonged usage of B100 in an engine built for diesel.

B. PHYSICAL PROPERTIES OF COCONUT OIL

1. Coconut oil is a fat consisting of about 90% saturated fat. The oil contains predominantly medium chain triglycerides, with roughly 92% saturated fatty acids, 6% monounsaturated fatty acids, and 2% polyunsaturated fatty acids. Of the saturated fatty acids, coconut oil is primarily 44.6% lauric acid, 16.8% myristic acid , 8.2% palmitic acid and 8% caprylic acid. Although it contains seven different saturated fatty acids in total, its only monounsaturated fatty acid is oleic acid while its only polyunsaturated fatty acid is linoleic acid.
2. Unrefined coconut oil melts at 24-25°C (76°F) and smokes at 177°C (350°F) while refined coconut oil has a higher smoke point of 232°C (450°F).
3. Among the most stable of all oils, coconut oil is slow to oxidize and thus resistant to rancidity, lasting up to two years due to its high saturated fat content .In order to extend shelf life, it is best stored in solid form (i.e. below 24.5°C [76°F]).

C. COCONUT OIL IN DIESEL ENGINES

Coconut oil has been tested for use as a feedstock for biodiesel to be used as a diesel engine fuel. In this manner it can be applied to power generators and transport using diesel engines. Since straight coconut oil has a high gelling temperature (22-25°C), a high viscosity, and a minimum combustion chamber temperature of 500 °C (932 °F) (to avoid polymerization of the fuel), coconut oil is typically transesterified to make biodiesel. Use of B100 (100% biodiesel) is only possible in temperate climates as the gel point is approximately 10°C (50 degrees Fahrenheit). The oil needs to meet the Weihenstephan standard for pure vegetable oil used as a fuel since otherwise moderate to severe damage from carbonization and clogging will occur in an unmodified engine.

Use of Coconut Oil in Standard Engines

Figure 1 gives an overview of the options to use coconut oil in Compression (Diesel) engines. Coconut oil can be blended with diesel, straight in an adapted engine or turned into biodiesel. Because of higher specific density and slightly lower energy content, specific fuel consumption using coconut oil is generally 8% higher. Many studies involving the use of vegetable oils such as coconut oil were conducted in the early 1980s. Short term engine testing indicates that vegetable oils can readily be used as a fuel or in a range of blends with diesel. Long-term engine research however shows that engine durability is questionable when fuel blends contain more than 20% vegetable oil. Especially deposits on the pistons, valves, combustion chambers and injectors can cause severe loss of output power, engine lubricant deterioration or even catastrophic failure to engines. Using pure coconut oil in standard engines is very attractive through its low cost; however it requires special technical supervision and may shorten engine life.

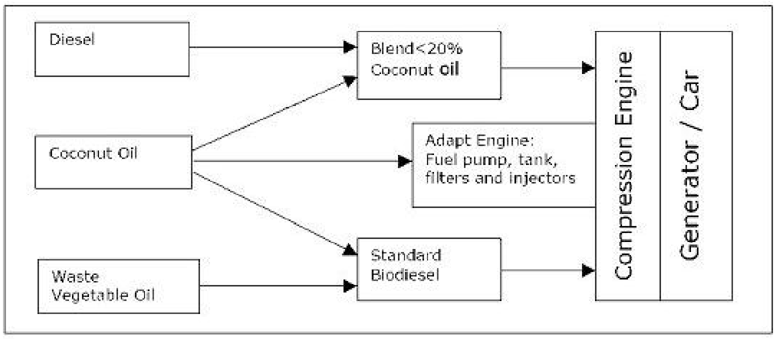

Figure 1. Overview of biofuel choices for compression engine

Use of Coconut Oil in Adapted Engines

a) Fuel Heater

As coconut oil has up to 30 times higher viscosity than regular diesel at the same temperature, most engine modifications include a fuel heater. As heat is exchanged between the engine coolant and the fuel, the oil viscosity approximates that of diesel. As coconut oil solidifies below temperatures of 25^0C, often an electrical heater is incorporated in the fuel tank.

b) Start / Stop on Diesel

Most adaptations incorporate a start and stop on regular diesel. As soon as the engine is operating at rated temperature, the fuel supply switches to coconut oil and just before shutting down; the supply is switched back to diesel. This system ensures that the fuel system has diesel ready for a cold start and avoids coconut oil residues in the fuel system.

Fuel System Adaptations

It is also possible to adapt the fuel system of a compression engine to start and stop on pure coconut oil. Mostly, these engines feature adapted injectors, dedicated fuel pumps and extra filters.

D. COCONUT BIO DIESEL IS BETTER THAN OTHER BIO DIESELS

1. It solidifies at approximately 25°C.
2. It operates better at approximately 70°C as the viscosity is lower.
3. Normal injector cleaning regimes remain in place for coconut oil.
4. A duel tank system works well starting and running the first 15min on petroleum diesel then switching over to coconut oil and end the days work in the reverse manner shutting down fore the last 15mins on petroleum diesel.
5. Coconut oil has less emissions and toxic fumes than petroleum diesel fuel
6. Coconut oil runs smoother and reduces engine knock.
7. Coconut oil is available to the producer in remote areas to run machinery and generate electricity when the roads are cut off in the wet or prices are too high.
8. Coconut Oil is a sustainable resource.

E. MATERIAL COMPATIBILITY

1. Plastics: High density polyethylene is compatible but PVC is slowly degraded. Polystyrenes are dissolved on contact with biodiesel.
2. Metals: Biodiesel has an effect on copper-based materials (i.e. brass), and it also affects zinc, tin, lead, and cast iron. Stainless steels (316 and 304) and aluminum are unaffected.
3. Rubber: Biodiesel also affects types of natural rubbers found in some older engine components. Studies have also found that fluorinated elastomers (FKM) cured with peroxide and base-metal oxides can be degraded when biodiesel loses its stability caused by oxidation. However testing with FKM- GBL-S and FKM- GF-S were found to be the toughest elastomer to handle biodiesel in all conditions.

II. BIO-DIESEL PROCEDURE

A. METHODS OF PREPARING BIODIESEL

There are at least three ways to run a diesel engine on bio-fuel, using vegetable oils, animal fats or both. All three are used with both fresh and used oils.

1. Mix it with kerosene (paraffin) or petro-diesel fuel, or with biodiesel, or blend it with a solvent, or with gasoline;
2. Use the oil just as it is -- usually called SVO fuel (straight vegetable oil) or PPO fuel (pure plant oil);
3. Convert it to biodiesel.

B. TRANSESTERIFICATION CHEMISTRY

The transesterification process is as described below.

Animal and plant fats and oils are typically made of triglycerides which are esters of free fatty acids with the trihydric alcohol, glycerol. In the transesterification process, the alcohol is deprotonated with a base to make it a stronger nucleophile. Commonly, ethanol or methanol is used. As can be seen, the reaction has no other inputs than the triglyceride and the alcohol.

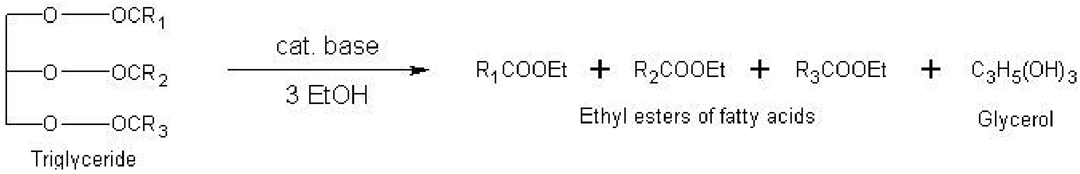

Figure 2. A reaction scheme for transesterification

R_1, R_2, and R_3 in this diagram represent long carbon chains that are too lengthy to include in the diagram.

Normally, this reaction will precede either exceedingly slowly or not at all. Heat, as well as an acid or base are used to help the reaction proceed more quickly. It is important to note that the acid or base are not consumed by the transesterification reaction, thus they are not reactants but catalysts.

C. SEQUENCE OF OPERATIONS

The final procedure we have adopted to prepare bio diesel for our paper is as given below:

1. Filtering
2. Acid titration
3. Mixing methoxide
4. Blending
5. Transfer
6. Settling
7. Washing
8. Drying

III. EXPERIMENT AND RESULT

Experiments have been conducted to find out flash point, fire point, kinematic viscosity, carbon residue and load tests in the internal combustion engines laboratory.

1. Flash and Fire points have been found out using Cleveland's open cup apparatus.
2. Kinematic viscosity has been found out using Red Wood Viscometer.
3. Carbon residue has been found out by Rams bottom apparatus.

Table 1 Properties of Biodiesel

	kinematic viscosity (cts)	density (g/ml)
diesel	3.71	0.775
coconut oil	33.8	1.085
bio-diesel	3.293	0.8843

A. FLASH POINT AND FIRE POINT

The flash and fire points of the bio diesel prepared by this procedure are 108 degrees and 110 degrees respectively. This value is very high compared to the values of ordinary diesel which is about 47 degrees and 56 degrees respectively. The higher flash point and fire point do not cause any interference with their working when used in an engine as has been observed during our experimentation. The higher flash and fire points actually make it easier and safer for the storage of bio-diesel than that of diesel. It also results in safer transportation.

B. CARBON RESIDUE

The carbon residue values obtained for coconut bio-diesel is 0.56% and for diesel it is 0.64%.This shows that coconut bio-diesel is a cleaner fuel than ordinary diesel.

C. DIESEL ENGINE SPECIFICATIONS

Bore (d) =80mm

Stroke length (l) =110mm
Compression ratio=16:1
Rated power (bp) =3.6 kw at 1500rpm
Rated speed=1500rpm
Orifice diameter = 20mm
Coefficient of discharge = 0.62

CALCULATIONS

AIR CONSUMPTION (M_a):

Ma= Density x Volume
Density=P/RT= 1.157
Where,
T=32º C

BREAK POWER (B.P):

b.p = 2∏NT/60000
T=9.81 x W x Re
Re = 0.1575m

FUEL CONSUMPTION (M_f):

M_f = V_f x Specific gravity of diesel x Density of water
V_f= (20/T) x 60 x 10^-6
T = Time for 20 ml of fuel flow
Specific gravity of diesel = 0.8275 cu.m/kg
Specific gravity of biodiesel = 0.8843 m^3 / kg

BREAK SPECIFIC FUEL CONSUMPTION (kg/kWhr):

Bsfc = M_f/B.P
A/F = M_a/M_f

INDICATED POWER:

I.P = B.P +F.P
F.P is taken accordingly from William's line

BREAK THERMAL EFFICIENCY (η_{bth}):

η_{bth} = B.P/ (Mf x C.V) x 100
C.V = 45MJ/Kg (diesel)
= 29.81MJ/Kg (bio-diesel)

MECHANICAL EFFICIENCY (ŋmech):

η_{mech} = B.P/I.P x 100

D. LOAD TEST

Table 2 D100 (100%DIESEL)

Load kg	B.P kW	Ma*10^{-3} Kg/s	Mf*10^{-4} Kg/s	A/F	Bsfc kg/kwhr	ŋbth	I.P kw	ŋmech
0	0	6.94	1.13	61.41	0	0	2.25	0
2	0.48	6.94	1.24	55.96	0.93	8.60	2.73	17.5
4	0.96	6.29	1.45	43.44	0.54	14.71	3.21	29.9
6	1.45	6.88	1.68	40.95	0.41	19.17	3.7	39.1
8	1.93	6.88	1.94	35.46	0.36	22.10	4.18	46.1

Table 3 B100 (100% BIODIESEL)

Load kg	B.P kW	Ma*10-3 Kg/s	Mf*10-4 Kg/s	A/F	Bsfc kg/kwhr	ŋbth	I.P kw	ŋmech
0	0	6.22	1.23	50.6	0	0	2.5	0
2	0.48	6.88	1.48	46.5	1.11	10.8	2.98	16.1
4	0.96	6.88	1.68	40.9	0.69	19.16	3.46	27.7
6	1.45	7	1.96	35.7	0.48	24.8	3.95	36.7
8	1.93	6.88	2.29	30	0.42	28.2	4.43	43.5

Table 4 B8O (80% BIODIESEL)

Load kg	B.P kW	Ma*10-3 Kg/s	Mf*10-4 Kg/s	A/F	Bsfc kg/kwhr	ŋbth	I.P kw	ŋmech
0	0	5.49	1.21	45.37	0	0	2.25	0
2	0.48	6.88	1.47	46.8	1.1	10.95	2.73	17.5
4	0.96	6.88	1.70	40.47	0.63	18.9	3.21	29.9
6	1.45	6.88	1.92	35.83	0 .47	25.3	3.7	39.1
8	1.93	6.88	2.21	31.13	0.41	29.2	4.17	46.1

Table 5 B60 (60% BIODIESEL)

Load kg	B.P kW	Ma*10-3 Kg/s	Mf*10-4 Kg/s	A/F	Bsfc kg/kwhr	ŋbth	I.P kw	ŋmech
0	0	4.16	1.41	29.50	0	0	2.35	0
2	0.48	5.83	1.49	39.12	1.1	10.8	2.83	16.96
4	0.96	5.94	1.73	34.33	0 .64	18.6	3.31	29
6	1.45	5.94	1.96	30.3	0.48	24.8	3.8	38.1
8	1.93	5.94	2.23	26.63	0.41	29	4.28	45

Table 6 B40 (40% BIODIESEL)

Load kg	B.P kW	Ma*10^{-3} Kg/s	Mf*10^{-4} Kg/s	A/F	Bsfc kg/kwhr	ηbth	I.P kw	ηmech
0	0	5.38	1.21	44.46	0	0	1.7	0
2	0.48	5.94	1.37	43.35	1.02	11.7	2.18	22
4	0.96	5.94	1.6	37.12	0.6	20.12	2.66	36
6	1.45	5.94	1.86	31.93	0.46	26.15	3.15	46
8	1.93	5.94	2.13	27.78	0.39	30.3	3.36	53.1

Table 7 B20 (20% BIODIESEL)

Load kg	B.P kW	Ma*10^{-3} Kg/s	Mf*10^{-4} Kg/s	A/F	Bsfc kg/kwhr	ηbth	I.P kw	ηmech
0	0	4.74	1.22	38.85	0	0	1.85	0
2	0.48	5.94	1.38	43.04	1.03	11.6	2.33	20.6
4	0.96	5.94	1.62	36.66	0.6	19.8	2.81	34.1
6	1.45	5.94	1.86	31.93	0.46	26.15	3.3	43.9
8	1.93	5.94	2.13	27.88	0.39	30.3	3.78	51

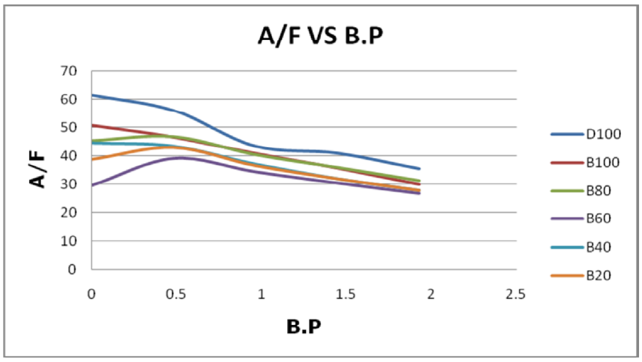

Figure 3. A/F Vs B.P

From A/F vs B.P graph it can be seen that A/F decreases as B.P increases. This implies that fuel consumption increases as Break Power increases. The graph hence shows that fuel consumption for D100 i.e. diesel is the least while that of B60 is the highest. After D100 the most desirable fuel consumption corresponds to the B100 curve.

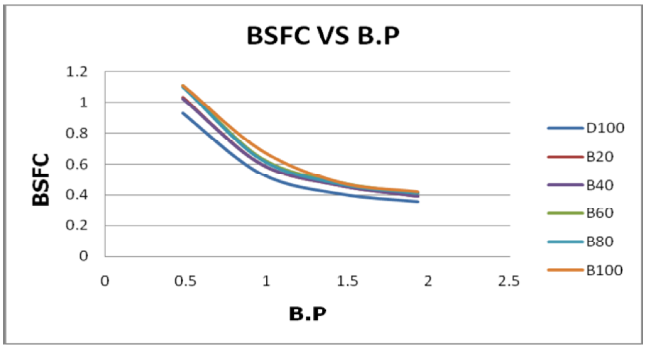

Figure 4. BSFC Vs B.P

It can be inferred from the graph that as B.P increases BSFC decreases. As per the formula we can see that BSFC is indirectly proportional to BP. We can observe that BSFC of diesel is the least of all the other curves, and that of B100 is the most. It should be noted that in the graph, B20 curve overlaps the B40 curve.

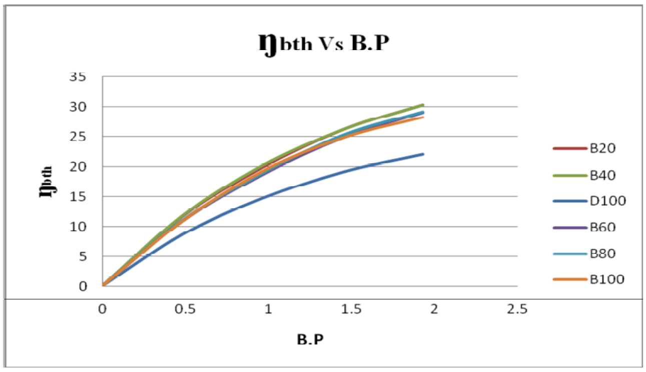

Figure 5. ηbth Vs B.P

This graph shows that as B.P increases break thermal efficiency also increases. Thermal efficiency is the highest for B40 while it is the lowest for D100. Thermal efficiency of B40 is observed to be much higher than the thermal efficiency of diesel. The thermal efficiency of B100 is also fairly satisfactory enough to be used directly without any blending.

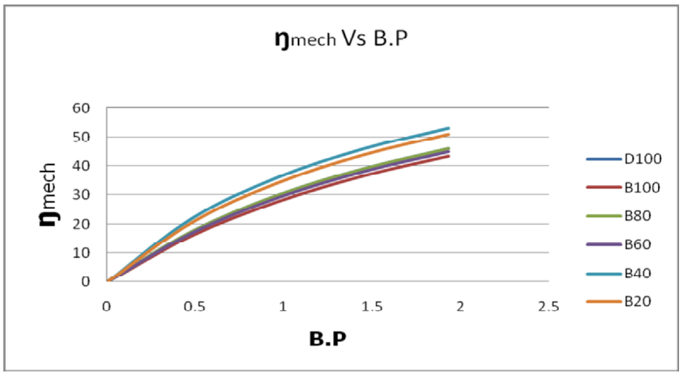

Figure 6. ηmech Vs B.P

Also the mechanical efficiency of B40 is only higher than the rest of the blends and fuels. The mechanical efficiency of B80 and D100 overlap while the efficiency of B100 is the least. Overall, B100 itself is quite satisfactory though with lowers efficiencies, while the most efficient of all comes out to be B40 but its fuel consumption is a little high. B100 can be used with fair results in case of acute shortage of diesel but the best of all the blends and B100 is the B40 blend.

IV.CONCLUSION

Performance and emissions of diesel engine fueled with blends of biodiesels of coconut oil with diesel fuel are experimentally investigated. The results of study may be summarized as follows:

1. Coconut oil based biodiesels can be directly used in diesel engines without any modifications.
2. The performance is slightly reduced while brake specific fuel consumption is increased when using biodiesels.
3. BSFC of diesel is the least of all the bio-diesels, and that of B100 is the most.
4. Brake thermal efficiency is the highest for B40 while it is the lowest for D100.The mechanical efficiency of B40 is only higher than the rest of the blends and fuels

REFERENCES

[1] Rushang M., 'Flow properties of biodiesel fuel blends at low temperatures'. Pp.143-151.

[2] Engler, C.R., Johnson, L. A., Lepori, W.A. and Yarbrough, C.M. 1983,'Effects of processing and chemical characteristics of plant oils on performance of an indirect-injection diesel engine'. JAOCS (Journal of American Oil Chemists Society). pp. 1592-1596.

[3] Meher, L.C., Vidyasagar, D. and Naik, S.N. 2004, 'Technical aspects of biodiesel production by transesterification-a review'. Renewable and Sustainable Energy Reviews XXL. pp. 1-21.

[4] Mohamad, I. Al-Widyan and Ali, O. Shyoukh. 2002, 'Experimental evaluation of the transesterification of coconut oil into biodiesel', Bioresource Technology. Vol. 85.

[5] V. V. V. Ramesh Reddy, Y. V. Ramana Murthy and G. Venkateswara Rao, 'Comparison Of Performance Characteristics Of Diesel Engine Fuelled With Raw Coconut Oil Blends And Diesel',Vol. 2 Issue 4, April – 2013.

[6] Lovekush Prasad, Dr. Alka Agrawal, 'Experimental Investigation of Performance of Diesel Engine Working On Diesel and Neem Oil Blends', IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE) ISSN : 2278-1684 Volume 1, Issue 4 (July-August 2012), PP 48-51.