Bio-Diesel Burner Design for Rural Thermal Application

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Abstract— The developing biodiesel field almost reached good height in the transport sector and it is more in advanced studies in transport sector. The foot print of biodiesel in domestic applications will have huge changes in the fuel economy. The replacement of kerosene with biodiesel will be the one best option. This paper contains the work for designing biodiesel burning pressure stove. This pressure stove can reduce the dependency on fossil fuels. This paper contains experiments and results that deal with comparison of kerosene stove and biodiesel. The design of the biodiesel burner was proposed in this paper.

Key words: Biodiesel; Burner; Domestic application

I. INTRODUCTION

Biodiesel is widely spreading revolution in case of fuel replacement mainly in transportation sector and many researches are going on for using biodiesel in higher ratio. The role of biodiesel in rural thermal application can lead to really a huge improvement in economy. In India, almost 28000 crore rupees are spent as subsidy on kerosene, which leads to the compensation burden on other fuels like petrol, diesel and LPG. The fuel price hike leads to many other price modifications which is the very hot topic nowadays. Apart from these economic issues, almost half of the world's population use coal, wood, charcoal, dung, or kerosene as indoor cooking fuel. The World Health Organization (WHO) estimates that about four thousand people, predominantly children, die every day as a result of emissions from those cooking fuel. Thus this paper mainly focuses on replacing kerosene with Biodiesel as a fuel for cooking.

The purpose of this paper is to compare the fuel properties of Jatropha Bio-diesel and Kerosene. The performance test on kerosene wick stove by using biodiesel stove was conducted. The design of biodiesel wick stove is proposed**.** The performance test on pressure kerosene stove by using biodiesel was done. The design of biodiesel burner was proposed and the working of it is tested.

II. ECONOMIC ANALYSIS

Subsidy given for kerosene = Rs.32 / L
Market price of kerosene = Rs.15/L
Kerosene usage in INDIA =202000barrels /day
1 barrel = 119L
Subsidy spent on kerosene = 28000 crores/year
Yield of Jatropha seeds = 10000kg/hectare
Cost of Jatropha cultivation = Rs.24656.25/hectare
3.28 kg of Jatropha seeds = 1 litre of biodiesel
Cost of producing Biodiesel= Rs.9.5/kg of Biodiesel
1kg of Biodiesel = 1.2486666 Litre
Total cost of producing Biodiesel = Rs. 15.66/-
(Tamilnadu agricultural University)
Profit = Rs.5/-
Market price ≈ Rs.21/-
Subsidy that has to be given for Biodiesel (in order to provide the fuel for Rs.15/L) =Rs.6/L
Considering same efficiency as Kerosene Stove,
Subsidy for Biodiesel = Rs.5260 crores
Savings in subsidy = Rs.22740 crores
Considering half the efficiency of Kerosene stove,
Subsidy for biodiesel = Rs.10520 crores
Savings in subsidy = Rs.17480 crores
Considering 1/4rth efficiency of Kerosene Stove,
Subsidy for Biodiesel =Rs. 21040 crores
Savings in subsidy = Rs.6960 crores

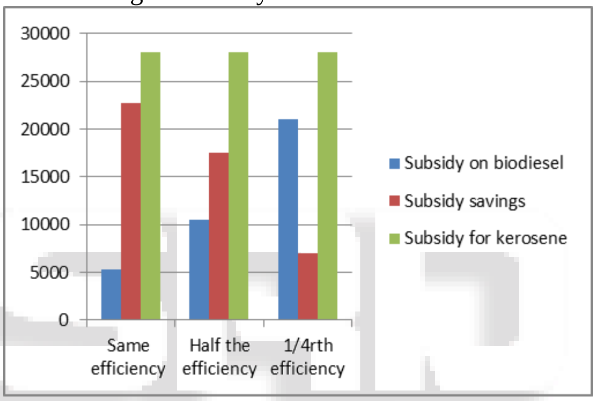

Fig. 1:

A. *Land Requirement*

Considering Same Efficiency as Kerosene Stove,
Fuel Required = $8.7 * 10^{9}$ L /Year,
Seeds Required = $2.8778 * 10^{10}$kg of Jatropha
Land Required = 29 lakh Hectare
Considering half the Efficiency of Kerosene Stove,
Fuel required = $17.4 * 10^{9}$ L /Year,
Seeds Required =$5.7556 * 10^{10}$kg of Jatropha
Land required = 58 lakh Hectare
Considering 1/4rth efficiency of Kerosene Stove,
Fuel required = $34.8* 10^{9}$ L /Year,
Seeds Required =$11.511 * 10^{10}$kg of Jatropha
Land required = 116 lakh Hectare
Available cultivatable Waste Land (2007-2008) =131.2 Lakh Hectare

III. BIODIESEL

Biodiesel is a mono-ester of alcohol, most commonly methanol or ethanol. The Process of transesterification can convert the oil into methyl ester (i.e., Biodiesel).The production of biodiesel starts from Oil Extraction from the seed selected. Here in this paper the Jatropha Curcas has been selected as a seed.

A. Jatropha Curcas

Jatropha is a wildly growing hardy plant, in arid and semiarid regions of the country on degraded soils having low fertility and moisture. It can be cultivated successfully in the regions having scanty to heavy rainfall. Even it can be cultivated even on fallow and barren lands. Jatropha is having potential as medicinal plant too. (Gubitz et al, 1999).

B. Transesterificaiton

Transesterification is the process by which biodiesel is produced. In this process an ester reacts with an alcohol to form another ester and another alcohol. The catalyst for this reaction is KOH or NaOH. Three moles of methanol react with one mole of triglyceride which produces mixture of fatty esters and glycerin. The primary input is assumed to be oil that has been extracted from Jatropha oilseed. To accomplish the transesterification reaction described above, the oil, methanol, and catalyst are mixed together in a stirred reactor. 55º-60ºC temperatures will cause the reaction to reach equilibrium more rapidly; in most cases the temperature is kept below the normal boiling point of the methanol (65ºC) so the reactor does not need to be pressurized. Three moles of methanol react with one mole of triglyceride. In practice, most producers will use at least 100% excess methanol (6:1 molar ratio) to force the reaction equilibrium towards a complete conversion of the oil to biodiesel. The reaction is slowed by mass transfer limitations since at the start of the reaction the ethanol is only slightly soluble in the oil and later on, the glycerin is not soluble in the methyl esters. Since the catalyst tends to concentrate in the glycerin, it can become unavailable for the reaction without agitation. A common approach to overcome this issue is to conduct the transesterification in two stages. First, the oil is combined with 75% to 90% of the methanol and catalyst and this mixture is allowed to react to equilibrium. Then, the glycerin that has formed is separated by gravity separation and the remaining 10% to 25% of the methanol and catalyst is added for a second reaction period. At the conclusion of this second reaction period, the remaining glycerin is separated and the biodiesel is ready for further processing. The glycerin separation steps are usually accomplished by gravity settling or with a centrifuge .After the biodiesel is separated from the glycerol, it contains 3% to 6% methanol and usually some soap. If the soap level is low enough (300 to 500 ppm), the methanol can be removed by vaporization and this methanol will usually be dry enough to directly recycle back to the reaction. Methanol tends to act as a co-solvent for soap in the biodiesel, so at higher soap levels the soap will precipitate as a viscous sludge when the methanol is removed.

C. Properties

Properties	Jatropha biodiesel	Kerosene
Density g/cm ^{3}	0.88	0.81
Flash point (ºc)	>130	40-65
Caloric value (MJ/Kg)	37	43-46
Kinematic viscosity at 40^0c(cst)	4.84	1.46
specific gravity	0.88	0.81
cetane number	52	38
Carbon	77.1	86.25
H_2	11.81	13.42
Oxygen	10.82	-
sulphur	<0.001	0.3286

Table 1: comparison of properties of biodiesel and kerosene

1) Experiments 1 with Biodiesel:

Since the Biodiesel is going to be tested in Kerosene stove, the viscosity of kerosene and biodiesel were compared, there lies the most difference (Table 1) First some basic tests were done using Biodiesel,like the flame properties of biodiesel and kerosene was tested and it can be shown in following photos,

Fig. 1: comparison of flames of kerosene and biodiesel

The B100 was poured in the normal pressure Kerosene stove and it was pressurized .The Result was, No sprays found while pressurizing it .The Biodiesel started getting collected in the Spirit Cup below the burner. Thus the conclusion from the experiment is, the Biodiesel cannot be used in kerosene stove at normal conditions. Since the biodiesel is three times viscous than the kerosene , it cannot be used in normal kerosene stove at normal conditions.

2) Experiments with Biodiesel Blended Kerosene

Since the last experiment gave the negative result, biodiesel blended kerosene was checked in the same kerosene stove at normal conditions, before performing this experiment, the miscibility test was conducted, and The Biodiesel was mixed with kerosene in equal proportion and kept it to sit for two days. Result of this test is, The biodiesel is miscible in kerosene, It remains to be a homogeneous mixture over the time given for it. Thus the mixture can be used for experiments. The experiment begun with testing B10 (or K90)in kerosene stove. The Result is, the performance of the mixture in kerosene stove is almost matches the performance of kerosene in the same. Then the experiment continued with B20 (or K80).The performance started degrading, the Biodiesel gets collected in the spirit cup. Even though the miscibility test shows that kerosene and biodiesel are miscible, the vast differences in their Flash point causes the kerosene to get burnt first, Thus leads to irregular combustion. This continued in the case of B30 ,B40, B50 till B80. B90 responded in the same manner as B100

3) Conclusion from the Experiments:

The main Problem in using biodiesel is its high flash point and its high viscosity. Thus the both can be reduced by preheating it. First the viscosity of biodiesel has to be reduced to that of kerosene .The effect of temperature on viscosity of Biodiesel was tested using Red Wood Viscometer and the result is as follows

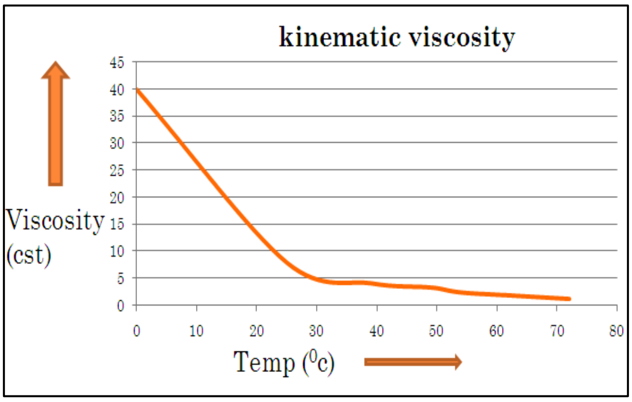

Fig. 2: viscosity vs temperature curve of biodiesel

Thus from the graph 1, it can be narrowed down that, in the temperature range of (60-80ºC) the biodiesel attains the viscosity of kerosene .

4) Experiments With pre heated Biodiesel

Taking errors into consideration, the range was kept as ±10ºc. The biodiesel was indirectly heated. The temperature was kept at 50 ^{0}c to 100 ^{0}c with the increment of 10^{0}c. The pre heated biodiesel was poured in the normal kerosene stove**.** The stove was pressurized and the result is observed .When pre heating was done and used, in normal kerosene stove the biodiesel dint catch fire The biodiesel was not vaporized enough to catch fire for sustained use .But the spray length of the fuel increased during every 10 deg raise in temperature.

5) Experiment No: 2

The spirit cup was first filled with kerosene. The kerosene was ignited the tube was allowed to get heated up. Then the biodiesel was pressurized. In this experiment also the biodiesel dint get vaporized But the result was exactly like the result of 100^{0}c preheated Biodiesel in kerosene stove. The spray of biodiesel is shown in figure 2.

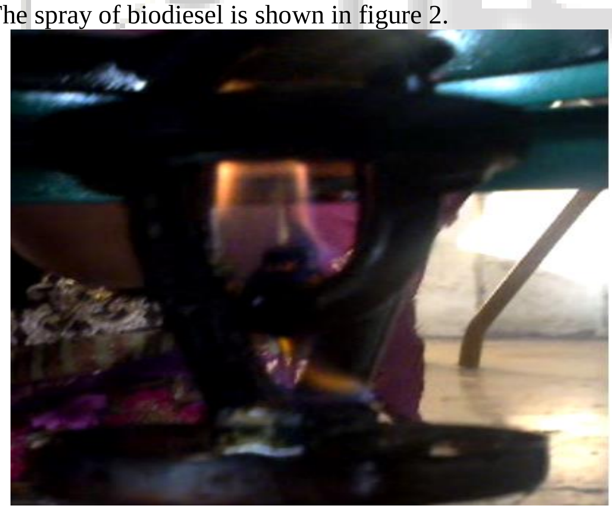

Fig. 3: Biodiesel spray

6) Result

Thus from the above two experiments, it can be interpreted that the kerosene stove nozzle is not suitable for biodiesel at any temperature. So the nozzle size has to be changed. The nozzle size of the normal kerosene stove is 0.3 mm Thus it has to be decreased and also the preheating arrangement has to be made in the burner. The biodiesel has to heat itself for sustained release of flame. Thus it needs to be initialized using kerosene in the spirit cup**.** Kerosene of 15 ml should be used in the spirit cup. The proposed model is shown in figure 3.

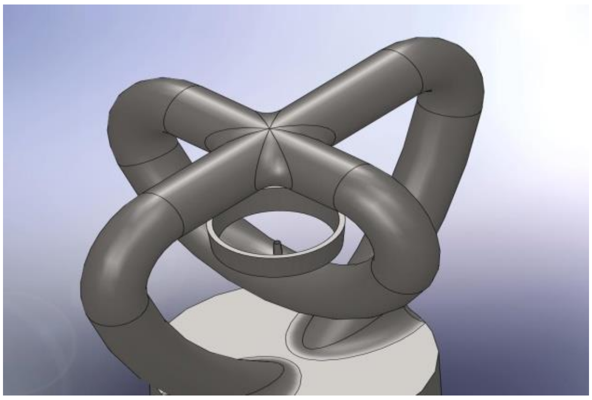

Fig. 4: proposed model no:1

7) Experiment with proposed model No1

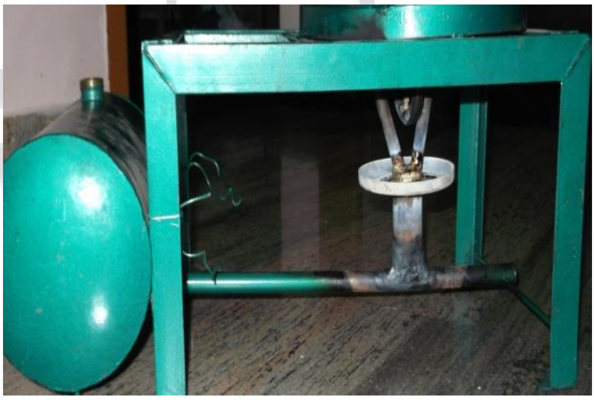

Fig. 5: fabricated model no:1

The spirit cup was first filled with kerosene. The kerosene was ignited. The tube was allowed to get heated up. Then the biodiesel was pressurized. There was an improvement in the performance of biodiesel in kerosene burner to this fabricated model. Even after the kerosene in the spirit cup gets over, the biodiesel continues to catch fire, where as in kerosene burner the biodiesel spray gets stopped when kerosene in the cup gets exhausted. But this needs modification, for commercial usage. The spirit cup diameter has to be reduced to focus the flame to the burner. The "gravity fed" technology can reduce mechanical pressure applied and can make the model safer. The corrections that can be made in the first model is shown in figure 5. This model is yet to be checked

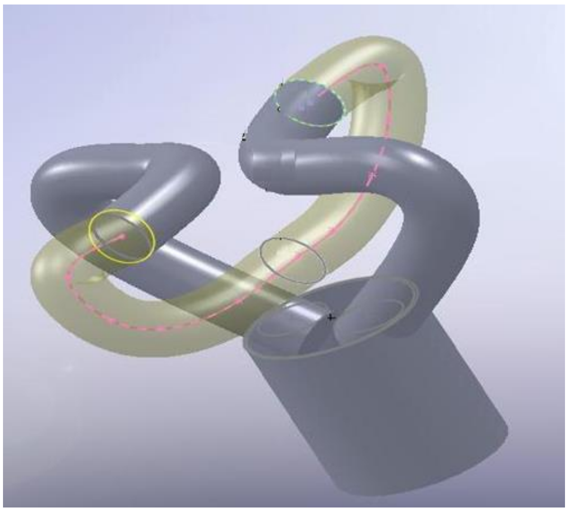

Fig. 6: proposed model no:2

8) Experiment with Gravity Fed Biodiesel Stove

Fig. 7: Gravity fed biodiesel stove

The gravity fed biodiesel stove is shown in the figure 6. In this set up the hose length is fixed to be 3.5m and the tank was filled with jatropha biodiesel and it was allowed to sit in the tank for two days. Then the spirit cup was first filled with kerosene and it was ignited. The tube was allowed to get heated up and the control valve was opened. The biodiesel flame and the performance of the burner was noted.

Fig. 7: Result of gravity fed biodiesel stove

9) Interpretation of the Result

The height between the burner and the tank is 3.5m.Since the flame height is too high, the length of the hose should be reduced to 2.5m.To make the flame focus, the wind shield must be provided.

10) Experiment with Biodiesel in Kerosene Wick Stove:

The biodiesel was poured in the normal kerosene wick stove and left it there for one hour .The biodiesel was allowed to undergo capillary action. Then it was lighted with candle, because it dint readily gets fire like kerosene. Then the result was observed. The flame was in yellow color controlled flame, no smoke, as in the kerosene wick stove. With some changes in this model, This can be a effective replacement of kerosene with biodiesel in places where wick stoves are still in practice. The result is shown in the figure 8.

Fig. 8: Result of biodiesel wick stove

11) Design of Biodiesel Wick Stove

In order for wick to operate, the maximum capillary head must be greater than the pressure drop required to transport the kerosene and the gravitational head

$(dp_c)_{max} > dp_1 + dp_g$

$(dp_c)_{max} = (2.\sigma)/r$ (in N/m^2)

Where σ=surface tension

r= radius of the wick Using Darcy's law,

$dp_1 = (\mu * l * m)/(\rho * k * A)$ (in N/m^2)

Where μ= dynamic viscosity ,

l= length of the wick,

m= transport rate,

ρ= density,

k= wick permeability,

A= area

$dp_g = \rho * g * h$ (in N/m^2)

Keeping K as constant (i.e., pore size, distribution and tortuosity (diffusion in porous media))

By comparing the properties of biodiesel and kerosene and with the help of above equations the modification that can be made is as follows:

- The cross sectional area of the wick can be made bigger for better flame strength and permeability
- The length of the wick can be made low.
- The outer frame can be kept nearer to the flame for effective utilization of heat

IV. Conclusion

Biodiesel is a good replacement of kerosene. Jatropha oil has potential as an alternative energy source. Its advantages are improved lubricity, higher cetane number, cleaner emissions (except for NOx), reduced global warming, and enhanced rural development. However, this oil alone will not solve our dependence on crude oil within any practical time frame. Use of this and other alternative energy sources could contribute to a more stable supply of energy and the subsidy savings. The main intention of replacing the kerosene with biodiesel is to reduce the subsidy burden on the other. Using this model the subsidy savings of 7000 to 22000 crores can be made. Hence this project is for developing the model to increase the efficiency of the biodiesel stove and decreasing the fuel consumption making it more profitable.

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