JNNCE Journal of Engineering & Management – A Peer Reviewed Bi-annual Journal
Available online @ https://jjem.jnnce.ac.in
ISSN: 2582-0079 (O)
Indexed in International Scientific Indexing (ISI)
Impact Factor Value: 1.025 for 2018-19
Volume: 3, Number: 1
January - June 2019

Solar Energy Assisted Prototype Biodiesel Plant to Convert Triglyceride into Fatty Acid Methyl Ester

Dr. Sreepathi L.K
Professor,
Dept. of Mechanical Engineering
Jawaharlal National College of Engineering, Shimoga-577204, Karnataka, INDIA

Chethan S.G.
Assistant Professor,
Dept.of Chemistry,
Jawaharlal National College of Engineering, Shimoga-577204, Karnataka, INDIA

Dr. M. H. Moinuddin Khan
Associate Professor,
Dept. of Chemistry,
Jawaharlal National College of Engineering, Shimoga-577204, Karnataka, INDIA

Abstract: Biodiesel is a nonconventional energy resource produced form non edible oil seeds. Transesterification process is the most commonly adopted technique to convert the non edible oil into biodiesel. During the production of biodiesel by transesterification process, electricity is being used to heat oil and for drying the biodiesel. About 20 kWh of electricity is used to produce 50 liters of biodiesel. Further, it is observed that before transesterification reaction the oil is heated at moderate temperature of 60^0 C. Hence, it is thought of using solar energy to meet this energy requirement as it is best suitable to meet low temperature energy demand. This paper contains the details of the work carried out in designing solar energy assisted biodiesel production unit. The performance study of the system indicates that, solar energy can be successfully used to produce good quality biodiesel saving large amount of conventional energy requirement. It is also observed that, such a system is particularly beneficial to rural India, where there is plenty of non edible oil seeds supply but the quality electrical supply is not assured.

Key words: Solar energy, Heat exchanger, biodiesel plant, biodiesel.

1. Introduction:

The consciousness of cleaner production technology is increasing globally. The need for alternative to fossil fuels has engendered extensive research in recent years. Fossil fuels are non-renewable sources of energy which generate pollutants and are linked to global warming, climate change and even some incurable diseases. The impending challenges and the environmental implications of fossil fuels have been reviewed widely in the literature (3, 9, and 10). Biodiesel has been identified as one of the notable options for at least complementing conventional fuels. Its production from renewable biological sources such as vegetable oils and fats has been reviewed widely (1, 2, 4, 6&7). Its advantages over petroleum diesel cannot be over emphasized it is safe, renewable, non-toxic, and biodegradable; it contains no sulphur; and it is a better lubricant. In addition, its use engenders numerous societal benefits: rural revitalization, creation of new jobs, and reduced global warming. Various methods have been employed in the production of biodiesel from oils and fats feedstock [5, 6, and 8].

A number of published articles investigated a simulated approach to evaluate some of these methods with a view to proposing cost effective alternatives [4, 7]. However, available simulated reports considered only pure materials as feed stocks. Pure feed stocks may not be realistic on a commercial scale.

Transesterification process is the most commonly adopted technique to convert the non edible oil into biodiesel. During the production of biodiesel by transesterification process, before treating with reagent, the oil is initially heated to 60-64oC using electric heater coils, Further; electricity is also being used for heating oil and drying the biodiesel. About 20 kWh of electricity is used to produce 50 liters of biodiesel. Further, it is observed that the heating of oil is carried out at moderate temperature of 600 C. Hence, it is thought of using solar energy to meet this energy requirement as it is best suitable to meet low temperature energy demand.

2. Material & Methods

The experimental set up consists of conventional esterification plant with few modifications as shown in Fig.1. The system consists of an evacuated tube solar water heater designed to get 200 liters of hot water at about 700c. The esterification tank consists of a heat exchanger coil through which hot water is made to circulate. A back up electric heating oil is also provided to ensure problem free working even in the absence of hot water supply.

Equipment used for solar transesterification unit:

1. Evacuated tube solar water heater system: evacuated solar water heater shown in Fig1, Evacuated tube act as an absorber in the solar water heater. Each evacuated tube consists of two glass tubes having vacuum in between them, which is an excellent insulator. The incident solar radiation falling on the tube passes through the outer transparent tube and strikes the outer of inner tube. It absorbs the heat energy and then passes to cold water flowing in the tube. An evacuated tube technology based solar water heating system is most energy efficient and cost effective.
2. Heat exchanger tank: The heat exchanger tank (Capacity: 15litres) shown in fig 3 is made up of mild steel. The tank is designed to a diameter of 24 cm and height 57cm. Bottom portion is conical shaped. The heat exchanger tank consists of a helical copper coil, a backup electrical heater and a thermometer to indicate temperature inside the tank.

a. Copper coil tube: A helical copper tube of coil diameter of 17cm and total length 26feet (8.23m) is inserted inside the heat exchanger tank. Hot water from the evacuated solar water heater is circulated inside the copper tube to heat non-edible oil in the tank.

b. Electrical heater coil: A backup electrical heater is provided to heat the oil when there is insufficient sunshine. This problem occurs especially during rainy season. It also helps in drying process where the Biodiesel is to be heated to a temperature of above 110°C.

3. Pump: A ½ HP pump is used to circulate the hot water from the storage tank to heat exchanger tank. Another pump (1/4 HP) is used to circulate the non-edible oil within the Heat exchanger tank to ensure uniform heating of the oil.

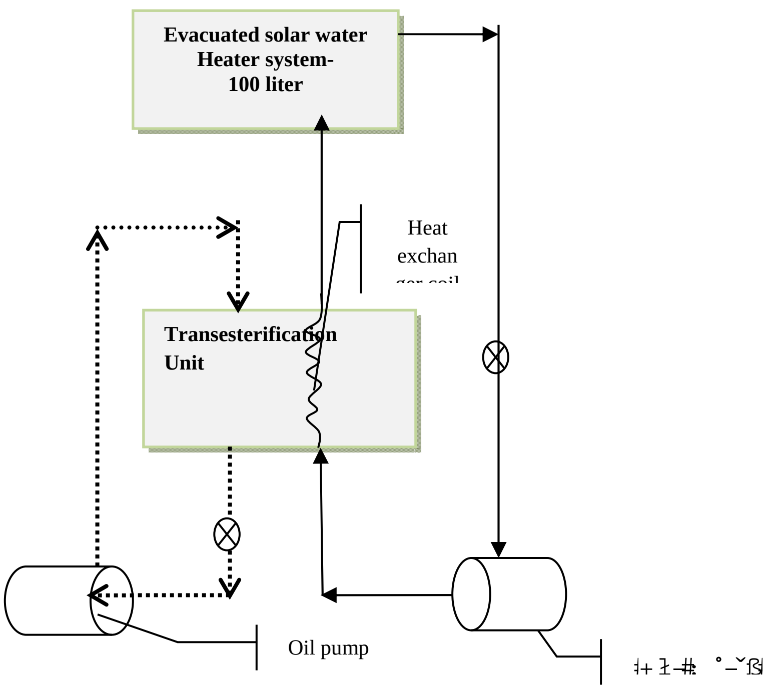

Fig1: Schematic diagram of Solar Assisted prototype biodiesel production plant

Fig2 Evacuated solar water

Fig.3: Transesterification

3. Working Principle:

Ten liters of non edible oil is added to heat exchanger tank. Hot water from solar water storage tank is made to circulate through the heat exchanger coil fitted inside the transesterification unit. The hot water heats up the oil. During heating oil is continuously churned with the help of a pump to achieve uniform heat distribution. Once the temperature of oil reaches 60-64oC, calculated amount of reagent (methanol + NaOH) is added and refluxed for about 1 hour by maintaining the oil temperature 60oC. The oil is allowed for cooling to separate biodiesel (FAME) and glycerol layer. After cooling glycerol layer is drained through the bottom valve. Biodiesel is washed with warm water obtained from solar water heater. Washed water is tested with phenolphthalein indicator till colorless solution is obtained. After washing process, biodiesel is again heated to remove moisture by passing hot water inside heat exchanger coil. An electrical heater is also used to raise the temperature of biodiesel to 1050 so as to remove moisture content completely. Biodiesel thus obtained is cooled and stored in a dry container.

4. Results and discussion:

An analysis of energy required for the production of biodiesel is made considering all the stages of biodiesel production. Further, the quality of biodiesel is also tested and compared with same obtained using electrical heating.

4.1. 4.1 Energy input for the production of biodiesel:

biodiesel: For biodiesel production, normally in industries electrical energy is utilized for heating oil, transesterification process and drying purposes. The total electrical energy requirement per liter of biodiesel production depends on capacity of the equipments. Table 1 and Table 2 give the electrical energy requirement for production of biodiesel considering all the energy inputs.

Table1: Electricity requirement for biodiesel production without solar energy.

SL NO	Transesterification process by Solar energy	Quantity per each batch in ltr	Electrical energy required kWhr
1	transesterification -2kw-3hr	10.0	0.0
2	heating water-8time-2kw		0.0
3	Water circulating pump ½ hp -3hr		1
4	Biodiesel Drying-1 KW- 1hr		1
	Total electrical energy		2.0

Table 2: Electricity requirement for biodiesel production using solar energy

blends	kinematic viscosity cst	flash point ^{0}c	fire point ^{0}c	specific gravity	copper strip corrosion test
Biodiesel produced by electrical energy	5.8	170	174	0.88	complies
Biodiesel produced by solar energy	6.0	175	180	0.94	complies

As shown in Table 1, about 4 units (kWhr) of electrical energy is required for the production of 10 liter of biodiesel without using solar energy while, with the use of solar energy, the electrical energy requirement is only about 2 kWhr(Table 2). Hence, a 50% savings in electrical energy is achieved. It may be noted that, in a scaled up system the energy savings would be still higher.

Another observation made during the Transesterification process is the time required for heating the oil and biodiesel drying. Table 3 indicates that, only six minutes is required to heat the oil from ambient to 600 C. Using electrical coils it takes around 9 minutes for the same process.

Table 3. Comparison of Time required for Biodiesel Production

SL NO	Transesterification process by Electrical energy	Quantity per each batch in ltr	Electrical energy required-kWhr
1	transesterification -2kw-3hr	10.0	1.2
2	heating water-8time-2kw		0.8
3	methanol recovery-2hr		1.2
4	Biodiesel Drying-2KW- 2hr		0.8
	Total electrical energy		**4.0**

4.2 Quality of Biodiesel: Biodiesel produced from solar transesterification unit is tested for Viscosity, Specific gravity, Flash point and copper corrosion and a comparison is made with the quality of biodiesel produced using electrical energy.

Table 4: comparison of biodiesel testing results with Biodiesel from solar transesterification unit:

Sl no	Energy Sources	Capacity of transesterification unit	Time taken to attain 60^{o}C	Time taken for completion of each batch
1	Electrical Energy	10 liter	9 minutes	13hrs
2	Solar energy	10 liter	6 minutes	9 hrs

5. Conclusions:

- Temperature required for transesterification reaction can be easily achieved by using evacuated solar water heating system.
- Highest temperature of Biodiesel attained by heat transfer is 65°C.
- Washing of biodiesel can be done using warm water taken from solar water heating system.
- Utilization of solar energy is economical and eco-friendly.
- Quality of the biodiesel produced using solar energy is comparable with that obtained using electrical energy input
- This system is beneficial for rural areas where there is scarcity of electricity and in future this system very needful for biodiesel production with by utilizing less energy.

Acknowledgments:

The authors acknowledge the funding provide for conducting the work by Biofuel Development Board, Govt. of Karnataka and Karnataka State Council for Science and Technology.

References:

1. Aransiola E, Betiku E, Ikhuomoregbe D, Ojumu T. Productionof biodiesel from crude neem oil feedstock and itsemissions from internal combustion engines. African Journal Biotechnology 2012;11(22):6178e86.
2. Aransiola E, Betiku E, Layokun S, Solomon B. Production of biodiesel by transesterification of refined soybean oil. IJBCS 2010; 4(2):391e9.
3. Chai F, Cao F, Zhai F, Chen Y, Wang X, Su Z. Transesterification of vegetable oil to biodiesel

using a heteropolyacid solid catalyst. Advanced synthesis of catalyst, 2007;349(7):1057e65

4. Gomez-Castro FI, Rico-Ramirez V, Segovia-Hernandez JG,Hernandez S. Feasibility study of a thermally coupled reactive distillation process for biodiesel production. Journal chemistry engineeruing process, 2010;49(3):262e9.
5. Jain S, Sharma M. Prospects of biodiesel from jatropha inIndia: a review. Journal of Energy resources 2010; 14(2):763e71.
6. Juan JC, Kartika DA, Wu TY, Hin TYY. Biodiesel production from jatropha oil by catalytic and non-catalytic approaches
7. Kiss AA. Heat-integrated reactive distillation process forsynthesis of fatty esters. Fuel Process Technology, 2011;92(7):1288e96
8. Ma F, Hanna MA. Biodiesel production: a review. Bioresource Technology 1999;70(1):1e15.
9. Muthu H, SathyaSelvabala V, Varathachary T, KiruphaSelvaraj D, Nandagopal J, Subramanian S. Synthesis ofbiodiesel from neem oil using sulfated zirconia via transesterification. Brazilian Journal of chemical Eng. 2010;27(4):601e8.
10. Sahoo P, Das L. Combustion analysis of jatropha, Karanja and Polanga based biodiesel as fuel in a diesel engine. Fuel 2009; 88(6):994e9.

***