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Research article

Design, Fabrication and Evaluation of a Novel Biodiesel Processor System

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Abstract

In this research work, to reduce the separation time of glycerin, increase in efficiency and purity of recovered methanol and pure biodiesel production, a novel biodiesel processor system is designed, fabricated and evaluated. In fabricated system, batch type stirred tank reactor (STR) with a capacity of 70 liters in which to more efficient mixing, two methods of mechanical and hydraulic mixing has been provided. In order to increase the purity and efficiency of methanol recovery process in designed system, facilities in the vacuum distillation method is provided. One of the innovations used in this system in addition of sediment glycerin separation, is utilizing electrostatic Coalescing method in separation of glycerin in which the high voltage / low current is used. Another innovation used in this system, is possibility of using ion exchange dry wash by absorbing column and magnesol powder as filter aid. All tanks, pumps, piping, valves are made from 316 Stainless Steel to ensure no erosion. Biodiesel produced by fabricated system showed close value to the requirements of biodiesel standard.

Keywords: biodiesel processor, glycerin separation, methanol recovery, dry wash purification.

1. Introduction

Transestrification is the most common method for biodiesel production in which, a reaction takes place. Biodiesel production takes place throughout an alcoholysis reaction known as transesterification, where triglycerides with an alcohol and a catalyst react to generate esters of the alcohol called biodiesel, and glycerol as a by-product [1-2]. Because vegetable oil and alcohol form two almost immiscible phases, no matter what type of catalyst is selected, a mixing of the two reagents is required in order to break the alcohol phase into small drops, thus providing sufficient interfacial area for the reaction [3]. Also, for intensifying the process, the reaction temperature should be increased. For this purpose a mixing system as biodiesel processor system should be prepared. The current Biodiesel

Processor Market is divided into 2 sections. The small-scale “Homebrew” section and the large scale “Chemical Plant” sized producers. The small-scale processors are batch production units and are usually capable of processing no more than 50,000 tones a year. The larger scale plants are also batch production units but are capable of producing biodiesel of over 10 million tones per year [4]. Today’s biodiesel processor has to be concerned with many issues, the least of which may be the cost of the capital investment. Knowledge of how to run a successful chemical plant is essential [5]. Considering the transesterification biodiesel process, most of biodiesel producion systems are not able to produce fuels according to related standards (EN14214, ASTM D6751). Therefore, a purification step is necessary. Crude biodiesel which is produced by transesterification method before being used as diesel fuel in order to meet requirements of standards should be purified after separation of glycerin and methanol recovery. There are two generally accepted methods to purify biodiesel: wet and dry washing. There are some disadvantages in wet washing of biodiesel such as high water consumption, emulsion formation, sewage output and drying of final product. Hence, considerable interest in biodiesel purification using a new method of dry washing is shown. Common methods in dry washing are using of ion exchange resins and magnesium silicate powder (magnesol) [6, 7, 8].

This paper details the development of a novel processor for the commercial and standard production of biodiesel. In this resesrch work, to reduce the separation time of glycerin, increase in efficiency and purity of recovered methanol and pure biodiesel production, a novel system is designed, fabricated and evaluated. In fabricated system, batch type stirred tank reactor with a capacity of 70 liters in which to more efficient mixing, two methods of mechanical and hydraulic mixing has been provided. In order to increase the purity and efficiency of methanol recovery process in designed system, facilities in the vacuum distillation method is provided. One of the innovations used in this system in addition of sediment glycerin separation, is utilizing electrostatic Coalescing method in separation of glycerin in which the high voltage / low current is used. Another innovation used in this system, is possibility of using ion exchange resins by absorbing column and magnesol powder as filter aid.

2. Materials and Methods

Design procedure

Reactor dimension

The first step in the design approach involved research on the technologies being used in the biodiesel production industry. These technologies include: ultrasound Technology [9], Microwave Technology [10], Continuous Oscillatory Flow Baffled Reactors [11], Spinning tube in tube reactor [12], Static mixer [13] and Agitated vessels. Research on the available technologies was carried out and it was decided that the stirred tank reactors (STR) technology was the common and simple process to make use of. In order to determinate the correct dimension of reactor, stress analysis due to fluid pressure and thermal stresses were carried out. Turbine impellers, particularly the flat-bade designs are frequently used for mass-transfer operations, the curved type is useful for suspension of fragile pulps, crystals and the pitched blade turbine more frequently for blending liquids. Flow pattern of liquid from the turbine impeller is radial except for pitched-blade type, where it is axial [14]. Considering the mentioned reasons, pitched blade turbine down flow with two inclined blades (45°) was selected. The maximum pressure in reactor by assumption maximum filling reactor and Considering the hydrostatic law was calculated as follow:

$$P = p_V + \sum \rho g H = p_V + (\rho_B H_B + \rho_G H_B) g \tag{1}$$

Density of biodiesel and glycerin were considered 893 and 1260 Kg/m^3, respectively also maximum vacuum pressure in reactor was 0.05 Mpa. With respect to height ratio of water to glycerin 0.1, maximum pressure in reactor by using equation 1 was calculated in 0.45 Mpa. Maximum peripheral stresses will be formed in the bottom of the reactor and where it connected to the cylinderical part of reactor so, the thickness of reactor wall by using equation (2) was calculated in 4 mm. Geometrical dimesions of reactor is illustrated in figure 1 and fabricated reactor showed in figure 2.

$$t_e = \frac{Pa}{\sigma_\theta}\left(1 - \frac{a^2}{2b^2}\right) \tag{2}$$

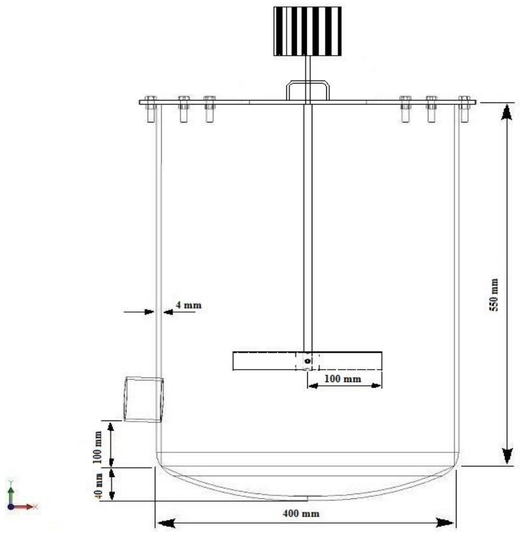

Figure 1. Geometric dimensions of reactor using agitating system.

Figure 2. Reactor installed on fabricated system.

Methanol recovery system design

Among the various types of heat exchangers that are used in industries, tubular heat exchanger is selected. Advantage of the tubular heat exchanger are capability of design for all pressure, temperature and flow, possibility of selecting various design pipe diameter, length and arrangement of core and economical aspects. Characteristics of fabricated methanol recavery system are given in table 1. Picture 3 shows the designed and fabricated methanol recovery system.

Table 1. Characteristics of designed heat exchanger.

Type	Shell and tube
Flow management	Single pass-countercurrent
Mechanism of heat transfer	Conduction Single phase (water)-dual phase (methanol)
Number of fluid	2 (water and methanol)

Figure 3. Methanol recovery system.

Glycerin separation system design

In this study, to separate glycerin from glycerin-biodiesel mixture, an electrostatic field caused by a high voltage (more than kV) and low amperage AC current (mA) is used. In this method, the process of coagulation particles or drops of glycerin in biodiesel-glycerin mixture from an electric field is done. Hence, in order to made different conditions of voltage and current, consumed power of system was calculated by the following equation:

$$P_E = V \times I = cte \quad (1)$$

Then, considering the constant electric power consumed, by changing the voltage of electrical circuit, the current with different value of amper were made.

2.3. Dry wash purification system design

According to mentioned reason about wet washing purification method, dry wash method was selected. In order to perform dry wash biodiesel purification process, two separation paths is

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considered. Use of ion exchange resins column and magnesium silicate powder (magnesol) as aid filter. Schematic of purification system is shown in figure 4.

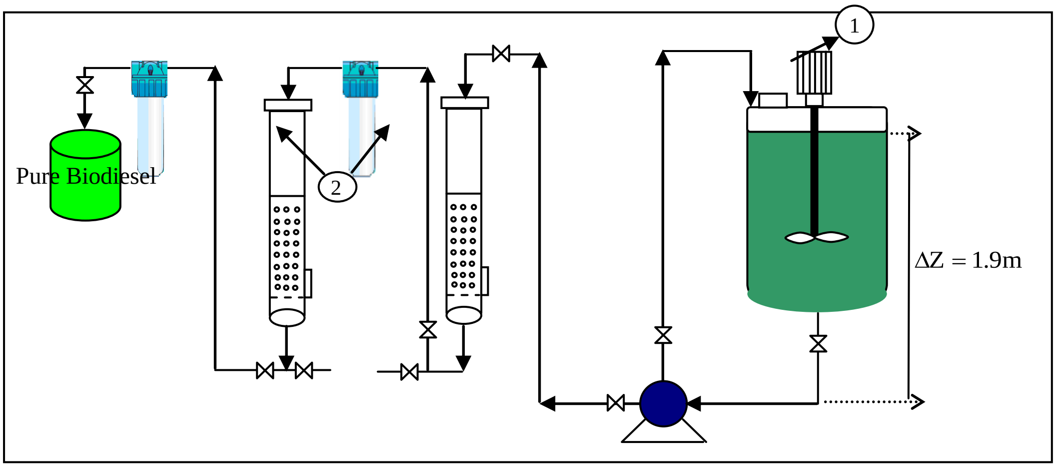

Figure 4. Shematic of purification system, 1: reactor, 2: absorbtion columns.

Fabrication procedure

In fabricated system, batch type reactor with a capacity of 70 liters in which to more efficient mixing, two methods of mechanical and hydraulic mixer has been provided. Methanol recovery process is done by using vacuum distillation method and glycerin separation carried out with sediment method and electrostatic Coalescing method. Also, in order to purification of biodiesel, possibility of using ion exchange resins by absorbing column and magnesol powder is provided. Figure (5), shows the fabricated biodiesel processor system.

Figure. 5: Biodiesel processor system.

3. Results and discussion

To evaluate the system, biodiesel fuel is produced by transesterification from waste cooking oil. Measurement of main characteristics of produced biodiesel shows that the results were consistent with standard fuel (table 2). Vacuum distillation method compared to simple distillation, reduced recovery time from 70 to 40 minutes and increased purity of recovered methanol from 89 to 97 percent.

Tab1 2. Characteristics of biodiesel produced by fabricated biodiesel processor.

Property	Test Method	Specification Limits	WCO biodiesel
Kinematic Viscosity - 40°C	ASTM D 445	1.9 – 6.0 mm^2/s	4.2
Water and Sediment	ASTM D 2709 0.050	maximum Vol. %	0.05
Flash point	ASTM D 93	130 minimum °C	178
Copper Strip Corrosion	ASTM D 130	No. 3 maximum	1a
Cloud Point	ASTM D 2500	Report in °C	-3
Ash sulfur	ASM D 874	0.020 maximum Wt %	0
Sulfur (S15)	ASTM D 5453	15.0 ppm maximum	0.0017

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Abbreviation

ρ	fluid density (Kg/m^3)
g	gravitational acceleration (m/s^2)
H	height of fluids in reactor (m)
p_v	relative vacuum pressure (Mpa)
σ_θ	peripheral stresses (Mpa)
p	Power (Kw)
I	Current (A)
V	Voltage (v)

References

[1] Lee SW, Herage T, Young B. Emission reduction potential from the combustion of soy methyl ester fuel blended with petroleum distillate fuel. Fuel, 83:1607–13 (2004).

[2] Ghobadian B, Najafi GH, Rahimi H, Yusaf TF. Future of renewable energies in Iran. Renewable and Sustainable Energy Reviews, 13: 689–695 (2009).

[3] R. Alamsyah, A.H. Tambunan, Y.A. Purwanto, and D. Kusdiana., “Comparison of Static-Mixer and Blade agitator Reactor in Biodesel Production” Agricultural Engineering International: the CIGR Ejournal. Manuscript 1566, Volume XII, March, 2010.

[4] Soetan, D. O., “Biodiesel processor design and manufacture”, Heap & Partners Ltd, UK and Liverpool John Moores University, UK.

[5] Anderson, D., Masterson, D., McDonald., B. and Sullivan, L, "Industrial Biodiesel Plant Design and Engineering: Practical Experience" *International Palm Oil Conference (PIPOC)*, 24-28 August 2003, Putrajaya, Malaysia.

[6] Berrios, M. and Skelton, R.L, "Comparison of purification methods for biodiesel", Chemical Engineering Journal, 144:459–465 (2008).

[7] Cooke B.S., Abrams S. and Bertram B, "Purification of biodiesel with adsorbent materials" US Patent, 0509959P, (2003).

[8] Vicente, G., Martínez, M., Aracil, J. "Optimisation of integrated biodiesel production Part I. A study of the biodiesel purity and yield" Bioresource Technology, 98: 1724–1733 (2007).

[9] Hernando, J., Leton, p., Matia, M.P., Novella, J.L. and Alvarez-Builla., J, "Biodiesel and FAME synthesis assisted by microwaves: Homogeneous batch and flow processes" Fuel. 86 1641–1644 (2007).

[10] Priyanka, C., Chintareddy., V.R., John G. V., and David., G. "Enhancing Biodiesel Production from Soybean Oil Using Ultrasonics" Energy and fueles, 24, (2010).

[11] M. Zhen g, R. L. Skelto n and M. R. Mackley, " Biodiesel reaction screening using oscillatory flow meso reactors" Trans IChemE, Part B, Process Safety and Environmental Protection, 85(B5): 365 – 371 (2007).

[12] Clemens, B., Norman, L., Paul, O., and Francois, R, "Evaluation of a Spinning Disc Reactor for Continuous Processing", Organic Process Research & Development, 5, 65-68 (2001).

[13] Thompson, J. C. and He, B. B. "Biodiesel production using static static mixers", Transactions of the ASABE, Vol. 50(1): 161-165 (2007).

[14] Treybal, R.E., "Mass-Transfer Operations" Third edition, *McGraw-hill book company* (1981).