IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719,
|| Special Issue || June-2019, || PP 61-65 ||

Comparative Analysis of Biodiesel Production Techniques

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Abstract: *Biodiesel is one of the best available sources to fulfil the energy demand of the world. It is commonly produced from lipid feedstock, animal fats and waste cooking oil by trans-esterification reaction. Considering, the depletion of fossil fuel, biodiesel is gaining more attention as a renewable and environmental friendly fuel. In this study we produce the biodiesel with help of different methods &compare these methods in order to improve the biodiesel production rate by converting waste cooking oil using reactive distillation catalysed by homogeneous catalyst. Conventional method is mainly based on emulsification of immiscible liquid by means of heating the raw fuel along with mechanical stirrer whereas ultrasonic bath method is done reactants by micro turbulence generated by radial motion of cavitation bubbles and the physical changes on the surface texture of the solid catalysts generating new active surface area. The intensity of cavitation process is greatly depends on the geometry of orifice plate generating cavitation phenomenon & can be characterized by cavitation no., by geometric coefficient α & β referring to sizes & shapes of orifice plate constituting cavitation reactor.The present study deals with development of a hydrodynamic cavitation reactor for biodiesel production based on the combined hydrodynamic cavitation and mechanical stirring processes.*
Keywords: *Biodiesel, Conventional Method, Ultrasonic Bath Method, Mechanical Stirrer, Hydrodynamic Setup, Orifice Plate.*

I. Introduction:

The increasing industrialisation & motorization of world has led to many problem & also due to scarcity & increase demand of fuel in day-to-day life, it has become necessary to reduce the usage of fuel based on petrol, diesel, etc. & has become essential to replace it with an renewable fuel which would have a lesser impact on environment & for this biodiesel could be a better option. Technically biodiesel can be defined , as a fuel comprised of monoalkyl ester of long chain fatty acids derived fromvegetable oil or animal fats. It is made by chemical reaction of lipids with alcohol which produces fatty acid ester.

In simple words biodiesel is an alternative fuel similar to conventional or fossil diesel which is prepared from straight vegetable oil, animal fats or waste cooking oil. In this paper, biodiesel is produced from waste cooking oil by reducing its viscosity with help of different methods such as dilution (blending), micro-emulsification, pyrolysis (thermal cracking) and trans esterification.

Transesterification is also called alcoholysis, it is a chemical reaction of an oil or fat with an alcohol in the presence of a catalyst to form esters and glycerol. It involves a sequence of three consecutive reversible reactions where triglycerides (TGs) are converted to diglycerides (DGs) and then DGs are converted to monoglycerides (MGs) followed by the conversion of MGs to glycerol.

The main objective of this paper is to produce biodiesel by 3different methods viz conventional method, ultrasonic bath method & hydrodynamic cavitation method & also to develop a hydrodynamic cavitation reactor.

Experimental setup:

1. Conventional Method:

This is the basic method for producing biodiesel by waste cooking oil with methanol and KOH as a catalyst .This process uses only heating for trans esterification process. It requires more processing time about 1-3 hours & more separation time about 5-10 hours. The % yield obtain is less as compare to other methods.

2. Ultrasonic Bath Method:

Ultrasonic bath method is an effective alternative method to achieve a better mixing in commercial biodiesel processing. This process uses heating as well as sound waves for trans esterification process. This process improves the trans esterification process by reducing the usages of methanol & catalyst for biodiesel production. This method requiresless processing time about 30min & less separation time about 60 min. Beside this it also increases the purity of glycerine and improves the %yield as compare to conventional method.

Fig.1. Setup of Conventional Method &Ultrasonic Bath Method

3. Hydrodynamic Cavitation Method:

Cavitation is defined as sequential formation, growth and rapid collapse of micro-bubbles or cavities in liquid medium with releasing large amount of energy within small time interval (in few micro seconds). On the basis of mode of generation there are four principle type of cavitation-

Hydrodynamic Cavitation: It is produced by pressure variation in a flowing liquid caused by the velocity variation in the system by changing the flow geometry of the flow system.

Acoustic Cavitation: It is a result of pressure variation in a liquid when ultrasound (sound with frequency greater than 16 KHz) waves pass through it.

Optic Cavitation: This type of cavitation is produced as a result of the rupture of a liquid due to high-intensity light or a laser.

Particle Cavitation: It is produced by any type of elementary particle beam (e.g., a proton) rupturing a liquid, resulting in cavitation.

Hydrodynamic and Acoustic cavitation occur as the result of tension prevailing in liquid while Optic and Particle cavitation occurs as the result of local deposition of energy in liquid. Hydrodynamic cavitation has a great scope of scale-up on an industrial scale due to its ability in generating cavitation at a much larger scale than acoustic cavitation.

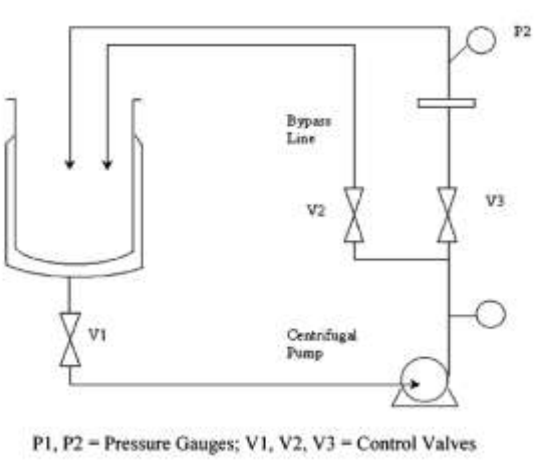

Fig.no.1 Schematic Diagram of Hydrodynamic Cavitation Setup

Fig.no.2. Setup of Hydrodynamic Cavitation Reactor

List of components:
1. Framework.
2. Tank.
3. Pipe Fitting.
4. Orifice plate.

5. Valve.
6. Pump.
7. Pump controller.
8. Flange.
9. Pressure gauge.
10. Strainer.
11. Cavitation Reactor

Working:

As pressure head increases, velocity of fluid through orifice plate also increases. But as the fluid passes through orifice plate there is a sudden pressure drop. It continues to drop till 'vena-contrata' is reached & then gradually increases until a maximum pressure is reached which is lower than pressure in upstream of orifice. Rate of flow increases, as pressure drop across the orifice increases.

Different geometric parameters such as α, β, β0 that are based on geometry of orifice plate, flow area of plate and structure of pipe helps to find the optimum design for the orifice plate.

No. of holes	Parameter			
	Hole dia.(mm)	α	β	β_0
1	10	0.40	0.5	0.25
25	2	2.00	0.10	0.25
16	3	1.33	0.15	0.36
20	3	1.33	0.15	0.45

Table no.1 Detail parameters of different orifice plate

Effect of parameter α:

$$\alpha=\frac{Total\ Perimeter\ \ of\ Flow}{Total\ flow\ area\ of\ Plate}$$

This is a dimensionless geometrical parameter. Higher the value of α higher is the conversion. α value depends on number of holes and size of the holes.

Effect of parameter β:

$$\beta=\frac{Hole\ Diameter\ \ of\ Orifice}{Pipe\ \ Diam\,eter}$$

This is a dimensionless parameter which depends on the size of the hole and size of the pipe. Smaller the value of β better is the cavitation intensity. Higher the number of holes greater is the conversion to biodiesel because more spots available for cavity generation.

Effect of parameter β0:

$$\beta 0=\frac{Total\ flow\ area\ of\ Orifice\ \ Plate}{Cross\ sectional\ \ flow\ area\ of\ pipe}$$

Increasing the value of β_0 increase the cavitation intensity. Orifice plates with same β0 but different number of holes show that plate with a greater number of small holes have greater cavitation intensity.

II. Result:

Comparative performance of hydrodynamic cavitation with ultrasonic bath and mechanical stirring by using waste cooking oil, frying oil & nagchampa oil as shown in table no.1

Citation	**Technologies**	**Source**	**Reaction time (min)**	**Conversion (wt%)**	**Yield Efficiency (g/J)x10^{-4}**
This study	Conventional method	Waste cooking oil	90	95	1.45
	Hydrodynamic cavitation		15	98	12.45
	Ultrasonic method		45	96	5.07
Ghayal et al. (2013)	Hydrodynamic cavitation	Frying oil	10	95	12.70
Gole et al.	Conventional method	Nagchampa	90	91	0.05
	Hydrodynamic		20	92	8.70

(2013)	cavitation	oil			
	Ultrasonic method		40	93	0.10

From this it can be understood that the hydrodynamic cavitation requires least reaction time & also the convension wt.% of yeild efficiency is highest for hydrodynamic cavitation as shown in table no.2

	MS	PU	HC
Energy consumption (Wh/Kg)	495	240	180

III. Conclusion:

The present study describes the production of biodiesel from waste sunflower cooking oil by using three production method viz. Conventional method, Ultrasonic Bath method and Hydrodynamic Cavitation method. A special effort has been taken for the design and development of Hydrodynamic Cavitation reactor. One of the important parameter which is responsible for the cavitation in hydrodynamic reactor is the design of orifice plate. The intensity of cavitation process greatly depends on the geometry of orifice plate generating cavitation phenomenon & can be characterised by cavitation number and. by geometric coefficient α & β referring to sizes & shapes of orifice plate constituting cavitation reactor. The outcome of experimental results is as follows:

1. Table no.1 gives detail study of the different properties of refined & waste cooking oil.
2. Comparison of different properties of biodiesel producedby different methods like Hydrodynamic Cavitation, Ultrasonic Bath & Conventional method is shown in table no.2. From this it can be understood that the reaction time is less for HC along with less energy consumption & with high % yield.

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