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Implementation of Normal and Fractal Baffles for Palm Oil and Methanol Mixing in Stirred Tank

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Abstract: Mixing is a vital process in a biodiesel reactor. It is known that turbulent flow is recommended for mixing process since it could mix the mixture thoroughly in an effective manner. Previous studies have proven that flow pattern, Reynolds's number are influenced by the impeller design especially blade number, blade type, and blade size. This study of comparison and stimulates the flow characteristics between normal baffled and fractal baffled stirred in mixing biodiesel reactor by using ANSYS Fluent software. The geometry of the model was modelled in Solidworks then imported to ANSYS Fluent software. The CFD simulation then was run with medium mesh and the *k*-epsilon turbulence model. The simulation run by Rushton impeller with a rotational speed of 150 rpm and number time steps are 1000, 1200, 1400 and 3600 seconds with 20 iterations. The satisfactory result of comparisons shows that different baffled to influence and strongly affects the flow characteristics at a different type of baffle. Based on the simulation result, the fractal baffles give better performance in mixing process compare to the normal baffle for this application.

Keywords: Bio-diesel, CFD, fluid mixing, mixing tank, Rushton blade

1. Introduction

Considered Biodiesel an alternative fuel and become more attractive as of late in view of it is ecological profits fuel which is made from renewable biological sources such as vegetable oils and animal fats. The cost of biodiesel is the primary obstacle to commercialization of the item [1]. Stirring, mixing, blending, homogenization, and emulsification are necessary unit operations in the manufacture of many pharmaceuticals, fuels products and are in most cases carried out in agitated tanks made of steel and sometimes equipped with a glass liner [2].

Mixing flow cut crosswise over very nearly every preparing industry including the concoction process industry; minerals, mash, and paper; waste and water treating and very nearly every individual methodology area. The specialist working with the requisition and configuration of blenders for a given procedure has three essential hotspots for data. One is distributed writing, comprising of a few thousand distributed articles and a few as of now accessible books, and pamphlets from supplies sellers [3]. For the blending process, a couple of challengers must to think about on the grounds that this methodology obliged long living arrangement time, high working expense, high vitality utilization and low of preparation proficiency. To comprehend all the challengers thinks about on biodiesel blend are creating focused around the strengthening innovations [4]. Flow is described as one or two components resulting from the mixer impellent in the tank. Often the stream pattern formed by an instigator becomes into the first sign of its suitability for a specific process. The allocation of the scattering of gas and solid molecule in a fluid usually relies on the kind of the stream pattern that prepared by the specific instigator in a given tank [6].

Most studies have been completed at the standard impeller leeway (one-third of the tank diameter). Furthermore, it has been demonstrated that the impeller clearance does Influence the liquid stream modality. In any case, it has been accounted for that the stream example created by the Ruston turbine transformed from the average two circles at a standard clearance to a solitary circle design at a low clearance. For multiple impeller systems, the most favourable clearance at which there is minimal intrusion among the flow generated by the top and lower impellers is the same as the tank diameter. Well-spaced impellers generate smooth and high fluid flows, which are characterized by mean velocity of the fluid and turbulence concentration [7,8].

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The homogeneous mixture is a mixture that has mixing element uniformly. There are several factors that influence the homogeneous mixture which are mechanisms of mixing, characteristics of materials to be mixed and characteristics of the mixer. To analyse a mixture, samples are taken from the mixture at random which represent the state of the mixture. The level of acceptable homogeneity of the mixture depends on each application. It can be specified in terms variation of coefficient, *CoV*. The standard *CoV* value equal to 0 represents a complete distributive mixing, while *CoV* value more than or equal to 1 represents total segregation [9].

Actually they have different between, methanol and ethanol, the ethanol is reacted with the triglycerides molecules in the oil, producing glycerine and alkyl esters of fatty acids (biodiesel) Worldwide, methanol is the most commonly used alcohol for biodiesel production, but the large-scale production of sugarcane in Brazil makes ethanol cheaper and easier to use for biodiesel production. Since ethanol is obtained from plant sugars and methanol is commonly produced from natural gas (or petroleum), the production of biodiesel by mixing of oils with ethanol (ethanolysis) represents a more sustainable pathway for this befoul production than that employing methanol (methanolysis). Methanolysis is a multiphase reaction, which occurs only at the boundaries of the methanol droplets dispersed in the vegetable oil phase [10,11].

1.1 **Fractal Concept**

Fractal is fundamentally a repeated shape and similarity toward oneself to a limitlessly little scale [12,13]. Homogeneous isotropic turbulence has been widely studied both experimentally in wind or water tunnels and numerically by Direct Numerical Simulations (DNS). Recently, used various multiscale (fractal) grids to generate turbulence in wind tunnels and found that complex multi-scale boundary/initial conditions can drastically influence the behaviour of a turbulent flow, especially when a fractal square grid is placed at the entry of a wind tunnel test section.

In these simulations, the fractal stirrers were mainly based on a square pattern with three multi-scale iterations and with a relatively small computational domain in the stream wise direction. There were also successfully performed DNS of turbulence generated by strategy [14]. The square grid fractal is as in Fig. 1 below.

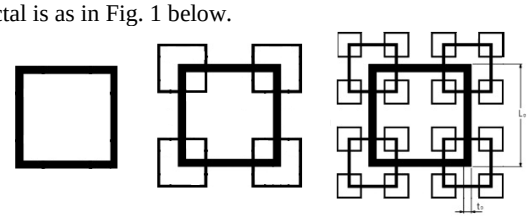

Fig. 1 - Construction of a panel fractal square grid based on three fractal iterations [10].

1.2 **Mixing Tank**

A mixing tank is one of the devices in engineering industries that is used for the continuous mixing of fluid materials. Generally, mixing tank is used to mix liquid, but it can also be used to mix gas streams, disperse gas into a liquid or blend immiscible liquids.

In industry, there are many types of mixing tank have been designed and it is used widely in industry [15]. However, there are many mixing tanks that have been proposed in the industry having complex and complicated in design. The type of mixing tank that usually used in industry is CSTR, PFR and BR tank. Each of mixing tank has its own arrangement and shape of mixer that is designed in order to get better efficiency to mix the fluid homogeneously. At the same time, each of the design requires a high cost of manufacturing and need to spend a lot of time in manufacturing and installation.

This research study will come out with a simple design of mixing tank and at the same time having standard efficiency of a mixer in order to reduce the current cost of manufacturing but still producing same results of mixing fluid as another mixing tank. In order to design optimal mixer geometries, appropriate tools and methods are needed to characterize the flow conditions and their influence on the mixing process. In this study, *CoV* will be applied in order to measure for presenting the uniformity of concentration at a cross section of the mixing tank. The simulation of mixing fluid can be simulated by using computational fluid dynamic (*CFD*) software. The simulation will predict the behaviour of fluid circulation and mixing within the tank. This study will focus on the simulation of fluid circulation and mixing within the tank at a specific distance of interest.

Mostly, main focused of this study is to propose a new approach of fractal concept (square grid fractal) for baffle in stirred tank. At the same time, the capability of fractal pattern in mixing process by determining the *CoV* will be determine. By the results, a recommendation for new concept of mixing in tank by using a fractal concept based on square grids fractal will be provide.

2. **Simulation Model and Methodology**

For the first step of the geometry drawing, the reactor drawing is done by using SolidWorks. Based on the actual geometry, 3D modelling using SolidWorks is constructed. The role of analysis in the reactor with the rotating 4-blades 90° design is to simulate the flow over a range of the operation. In this study, the fluid simulates at full load condition only with H=398 mm and T=300mm. The condition is due to the Ruston turbine and also 100 mm from the bottom was impeller position and there are two types of baffles, normal and fractal. After the drawing of the reactor is done drew in the Solid Works Software, the file is saved as IGES (*, igs) file then it is converted to the ANSYS Workbench.

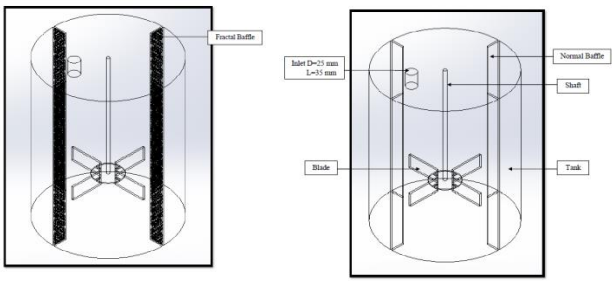

Fig. 2 - Full vessel geometry with normal and fractal baffles

Numerical simulation results could be performed in graphical form. The estimation of a variable is represented to in color. Volume fraction of fluid flow through the selected surfaces can be calculated as well. According to certain variables, fluid mixing is usually represented utilizing pathways color. An important part of simulation result is corroboration of the solution to check its rightness and to check the soundness of selected models. The system was first represented by the reactor entirely with palm oil and methanol. The rotational velocity of the impeller was set to 150 rpm.

The transient analysis took the results of the steady state analysis as an initial guess, and then a mixture containing methanol was injected into the palm oil vessel through the inlet pipe, as in Figure 2. Mesh deformation was applied to account for the increase in volume of liquid in the tank caused by the addition of the methanol mixture. The *k*-epsilon turbulence model was selected, since it is deemed suitable for a wide range of simulations, with relative low computational demand. In simulation of fluid mixing, there are several simulation results that want to be achieved by the novelist. The types of the result are volume fraction contours. This result will give details the behavior of homogeneous fluid mixing in the mixing tank. The visualization of contours was used to describe the magnitude of an erratic that reacts on the surface of the model. Basically, the various colors represent the amount and behavior of the model in visualization.

2.1 Coefficient of Variance (COV)

The *COV* is defined as the standard deviation of concentration, σ over the mean concentration, x for a given set of data points. The standard deviation of concentration is;

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n-1}} \quad (1)$$

where σ = standard deviation, n = number of data points, x = mean of the x_i and x_i = values of the data. An alternative measure of homogeneity is provided by the coefficient of variation;

$$COV = \frac{\sigma}{x} \quad (2)$$

Basically, the lower the value of *CoV* shows the better mixture quality. The required level of mixture quality is usually process specific. However, the *Co*V of between 0.01 and 0.05 is a reasonable target for most applications. This means that 95% of all concentration measurements to be taken from the tank cross section will be within ±2% of the mean concentration for *CoV*=0.01 and ±10% for *CoV*=0.05.

3. Results and Discussion

The results discussed on the distribution of local volume fraction for the dispersed phase which is methanol in palm oil for normal and fractal baffles in mixing tank. Fig. 3 shows the distribution of the local volume fraction for the normal baffles while Fig. 4 is the distribution of the local volume fraction for the fractal baffles after 3600 s. From the simulation, the volume fraction of distributed phase (methanol) and the *COV* could be resolved in order to define the mixing homogeneity level.

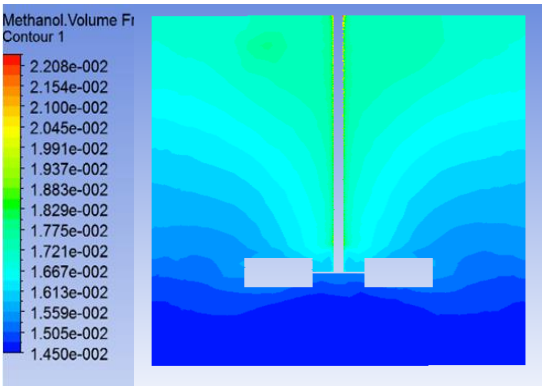

Fig. 3 - Distribution of the local volume fraction for normal baffles

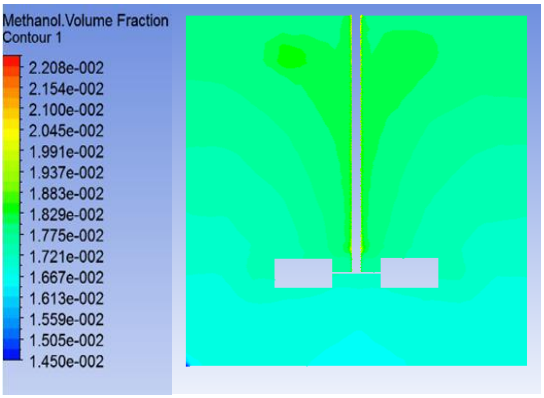

Fig. 4 - Distribution of the local volume fraction for fractal baffles

Table 1 show that the homogeneity level of the local volume fraction for normal and fractal baffles. It is clearly showed that the *CoV* for normal baffles is 0.0632 while for the fractal baffles, the *CoV* is 0.0424. According to the *CoV* value, the implementation of the fractal baffles was giving better mixing compare to the normal baffles. The *CoV* for the fractal baffles which is lower than 0.05 showed that the mixing tank equipped with a fractal baffles give a reasonable target for most applications.

Table 1 - Homogeneity level of the local volume fraction for normal and fractal baffles

	Standard deviation of volume fraction for methanol	Average of volume Fraction for methanol	Coefficient of variation , (*CoV*)
Normal baffles	0.00436	0.0691	0.0632
Fractal baffles	0.002379	0.0561	0.0424

Fig. 5 showed the rate of mixing for methanol in the tank for several time. From the graph, it showed that the time also become another factor in fluid mixing. The results for the normal baffles look quite slow in mixing performance in the beginning. However, the results after 3600 s look nearly close to the results for the fractal baffles. Therefore, it can be said that if we let the mixing process for a long time, there are maybe no effect on the implementation of the fractal baffles.

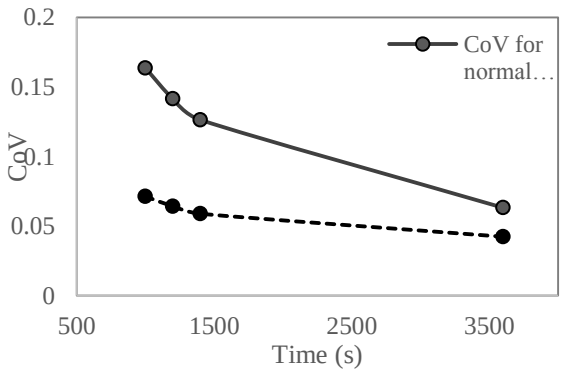

Fig. 5 - Comparison of *CoV* between normal and fractal baffles.

4. Conclusion

The aims of this study is to present the capability of the fractal pattern as a baffles in the mixing tank that can be enhance the mixing performance between ethanol and crude palm oil in bio-diesel process. The performance of the fractal baffles was proved by comparing the coefficient of variation for both type of baffles tested. As the lower the value of *CoV*, the better the mixture quality, the *CoV* for the mixing by using the fractal baffles give a value of 0.0424 which is lover that 0.5. Basically, the *CoV* of between 0.01 and 0.05 is a reasonable target for most applications. As a conclusion, implementation of the fractal baffles in the mixing tank is one of the best alternatives to enhance the mixing process if the time becomes one of the constraints in mixing process.

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