Qualitative Study of the Fluid Motion with Various Clearances of the Biodiesel Reactor by Using CFD

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Abstract:- The study based on the turbulent flow associated with the pitch blades turbines that installed at three clearances from the bottom in the reactor by using the standard k-ε turbulence model. The results showed that the flow behaviors is different for the three various location which installed at the C=T/4, C=T/2 and C=3T/4 for D=T/3. Good velocity distribution in the reactor produced atC=T/4. A comparison between the three impeller clearances in term of velocity distribution suggests that discharge flow from the blades that installed near the bottom of the reactor has strongly axial flow during mixing process.

Keywords:- Turbulence; Computational Fluid Dynamics; Impeller diameter; Impeller clearances; Flow pattern; reactor.

1 Introduction

Transesterification process is the displacement from an ester to the alcohol by another alcohol and the commonly suitable alcohols used is such like ethanol and methanol. Ethanol and methanol commonly used in biodiesel production due to the low cost and also physical and chemical beneficially [1]. In fact, although there are a little different ways and solution method define to produced biodiesel fuel, but the most of the manufacturing facilities in the globalization era nowadays usually produced it through the transesterification process because the process are easy and also be saving process.

Since 80 years ago, biodiesel produce from vegetable oil were used as the diesel fuels but it was used in the emergency situation only. The increasing of the biodiesel as an alternative fuel because in the automotive industries, the fuels can reduce the emission such like the particle matter (PM) and Carbon dioxides (CO₂). The reduction of the Carbon dioxides is essential requirement for environment. The terms of biodiesel referred to the Fatty Acid Alkyl Esters (FAAE) is produced from vegetables oil, animal fats or waste cooking oil feedstock [2].

2 Literature Review

Usually, the mixing process to create a reaction between two or more particles processing almost used the stirred reactors to complete the mixing process. Generally the stirred reactor in which one or more impeller is used in it to generate flow and mixing within the reactor are used for many kind of application. A basic mixing system comprises a vessel, container or reactor, which can be baffled or non-baffled, open or covered by a lid, a fluid or solid particles, and also with the an agitator which are mounted on a shaft. Perhaps, the agitator be the most critical part of the mixing system as it provide the source of the mixing energy and also determine the pattern of the flow, pumping and also the circulation rate in the reactor [3].

Generally, flow is defined as one or two components resulting from the action of the mixer impeller in the reactor or tank. Usually, the flow pattern created by an agitator are become the first indication of its suitability for a particular process. The distribution of the dispersion of gas and solid particle in a liquid commonly depends on the type of the flow pattern that produced by the particular agitator in a given tank or reactor [4].
Commonly, in the reactor during the transesterification, the process is very hard to make a fluctuating flow [5]. That is why the flow is become turbulent in the reactor. Besides that, low mixing intensity poses certain disadvantages during the mixing process. In general, the mixer characteristic with small diameter impeller and turning at a high speed, it will obtain a result in the fluid seeing the applied power as mostly shear. Compared to the low speed mixer with a larger diameter of the impeller, it will discharge a higher volume of fluid and thus resulting in high flow in the reactor. Most of the previous study stated the same reason about the flow pattern in that condition. Beside the fact that it will slows down the reaction in the reactor, low mixing intensity also responsible the delay in the response of the system during transesterification process [6].

3 Methodology

The biodiesel reactor used in this study was a standard configuration cylindrical vessel of diameter \( T=0.202 \) m and the liquid column height of \( H=T \) as shown in Figure 1. Impellers with diameter \( D=T/3 \) used at three clearances from the bottom of \( C=T/4 \), \( C=T/2 \) and \( C=3T/4 \). The fluids domain was Fatty Acid Methyl Ester (FAME) with density of 843 kg/m\(^3\) and viscosity of 0.00272 kg/(m∙s). The impeller rotational speed is 300 RPM and the Reynolds Number verification in turbulent regime. Impeller was subtract from the modelling before applying mesh. All solid boundaries with a no-slip condition for the flow field calculations. For the solver setup, the three dimensional simulation were performed by using the FLUENT version 14 and used the standard k-\( \varepsilon \) turbulence model. The solutions of the velocity field and the pressure were calculated using a second-order discretization scheme for the pressure, the SIMPLE scheme for the pressure–velocity coupling, and a second-order upwind scheme for the momentum calculation. For the post-processing, the various simulation data visualization tools of the Computer Fluid Dynamics solver setup to observe the results.

4 Result and discussion

4.1 Streamlines

Figure 2 shows the streamlines was fluctuating due to the rotating blade that affected the fluid motion. Since the blade start to moving with the increasing of speed, solids start to suspend off the vessel bottom and resulting into the well-known as loop of the flow pattern. Hence the blade is rotates, the fluid starts to swirl around the blade in the reactor. With the small clearance which is \( C=T/4 \), the fluid are most turbulent in the upper zone and bottom zone in the reactor. By increasing the clearance from the bottom to \( C=0.101 \) m, the streamline shows most of the flow translation are at the upper zone compared to bottom zone.

By increasing the clearance to \( C=T/2 \), the streamline almost accumulates at the upper zone of the reactor while the bottom region are still creates the fluctuating flow but not really strongly. Since increasing the clearance, the bottom zone is less of turbulent occur because the blade will force the circulation of the fluid created causes by contact to each other. In addition, turbulent is a very complex physical phenomena and made from high flow rate. In this case, the blade is rotates about the 300 RPM and that is enough to creates the turbulence in the reactor. But increasing the clearance from the bottom can reduced the turbulent region in the reactor. By the velocity streamline, clearly shown that the turbulent is fully developed when the blade are located near the bottom of the reactor. The most
important, the turbulence regions are created nearer the rotation blade region as well. High velocity are occurred at the blade and causes the strongly axial flow are created.

\[ C = T/4 \]

\[ C = T/2 \]

\[ C = 3T/4 \]

Figure 2: Streamlines created for three clearances of the 6-blades 45° pitch blade turbines

4.2 Velocity vector

Figure 3 shows the velocity vector of the fluid for three clearances from the bottom of the reactor. The result shows that axial circulation loop form at the tips of the blade and the most strongly axially loop form are creates by the blade at the clearance of T/4. There are two loop of the flows are creates at the upper and bottom of the reactor. When the axial flow hit the wall, it creates the recirculation of the flow which is the flow are forced to flow back as it was starting to move.

Since the clearance from the bottom are increasing, the axial flow are still creates with the two loop but these are not strongly as the lowest clearance condition. The bottom zone is differing from the upper zone because the turbulence flow region is less than the upper region. Increasing the clearances from the bottom can be noticed that the secondary lower loop generated below the blade. In both instances the secondary loop that created is much smaller compared to the first loop that is bigger.
Figure 3: Velocity vector in the reactor during the mixing process based on the three clearances of the 6-blades 45° pitch blade turbines

4.3 Velocity distribution

The velocity distributions graph has plotted based on the vertical plane and horizontal plane. By the analysis, the best and suitable condition of the blades diameter and clearances can be selected. In addition, the graph only focused on the velocity result because the velocity can be determined the flow pattern in the reactor either it highly or lower turbulence regime during the mixing process. Figure 4 shows the velocity distribution at the middle of the tank by using D=T/3 for each clearances of C=T/4, C=T/2 and C=3T/4. The result from horizontal plane actually based on the coordinate was exactly exerted in the middle of the reactor.

Figure 5 shows a changing pattern of the velocity result based on the clearances from the bottom due to the same diameter of blade. Clearly shown in the Figure 4 that when the blade installed at the bottom of the reactor which is C=T/4, the velocity resulted was better and becoming stable on the middle region of the reactor. Compared to the C=T/2, the velocity was higher because the reference point exactly at the location which the blade was installed. In this case, installing the blade at the top of the bottom not provided a good mixing because low velocity obtained at the middle of the reactor. These phenomena confirmed that at the bottom, the velocity become lowest compared to the middle region. It will made the mixing process was not really well in the reactor due to the poor velocity distribution.

5 Conclusion

In this study, a simulation of 6-blades 45° pitch blade turbines has been carried out in the turbulent regime. The effect of the clearances from the bottom of reactor has been investigated. The position
which where the blades was installed plays a great role on the flow structure. The results agreed that small clearances which is \( C=\frac{T}{4} \) was created a strongly axial flow in the reactor. The conditions plays an important role to make sure the fluids domain can be mixed together and accomplish the mixing process. These condition also made the fluids moved fluctuating and mixed together. These condition suitable because it can mixed the fluids particles together where the transesterification process includes two phase with high viscosity particles will accumulated at the bottom of the reactor. It seem that by installed the blades at the top of the reactor, the fluids domain cannot mixed well because only fluids in the upper region moved in high velocity compared to the fluids at the bottom reactor which is the particles moved by lower velocity only. These phenomena proved that the conditions is not suitable to accomplish the mixing process.

References