THE EFFECT OF OBSTACLE TYPES ON THE BEHAVIOR OF METHANOL BUBBLE IN THE TRIGLYCERIDE WITHIN THE COLUMN REACTOR BY USING CFD SIMULATION

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ABSTRACT

The aim of research is to show the effect of obstacle design utilization on the behavior of methanol bubble in the triglyceride liquid within the column reactor. A superheated methanol gas was introduced from the bottom of reactor contained triglyceride liquid to produce biodiesel through non-catalytic trans-esterification reaction. The process occurs under atmospheric pressure and temperature of 290oC. The result of research is intended to find the best design of obstacle to be used in the column reactor in order to increase the reaction rate of biodiesel production. The volume of fraction model of computational fluid dynamics is used to describe the behavior of bubble which is represented by the parameters of gas holdup, residence time, contact surface area and behavior of bubble. The previous study showed that those parameters influenced the reaction rate of biodiesel production. The volume of fraction model of computational fluid dynamics simulation were verified by compared the model result with the experimental result by using bench scale column reactor of biodiesel production on previous work. Eight types of obstacle were simulated to describe the bubble behavior of methanol in the triglyceride. The result showed that the utilization of obstacle which is constructed by single pivot and three of different perforate plates gives the highest gas holdup, contact surface area and residence time, respectively.

KEYWORDS*: Obstacle, methanol bubble, column reactor, computational fluid dynamics simulation.*

1.0 INTRODUCTION

Biodiesel as diesel fuel is becoming a crucial issue as a depletion of fuel surges the world. Biodiesel production technology has been developed both in terms of research and industrial application. The superheated methanol vapor bubble column is one of the methods of biodiesel production, where the methanol gas is introduced from the bottom of bubble column reactor into liquid of oil to produce biodiesel through trans-esterification reaction without catalyst. The reaction occurs at atmospheric pressure and temperature of 290^{o}C condition. Both of transeterification and esterification reaction take place simultaneously in this non-catalyst reaction therefore no purification process before and after the reaction as catalyst method did due to the existing catalyst. The limitation of non-catalyst method is the reaction rate of biodiesel production is very low. Reaction rate of biodiesel is influenced by methanol flow rate and reaction temperature (Joelianingsih *et.at*, 2008). Biodiesel is produced due to diffusivity force of methanol into oil or contact between methanol and oil if requiring of activation energy is fulfilled. The previous work (Wulandani et al, 2011) denoted that there was a positive correlation between contact surface area, gas holdup and reaction rate of biodiesel production. Several configuration of perforated plate installed in the cylinder obstacle have been simulated by computational fluid dynamics (CFD) method and have verified by experimental bench scale column reactor to produce biodiesel. Base on that result this paper focuses on how CFD simulation shows the effect of several types of obstacle utilization within the column reactor on the behavior of methanol bubble in the liquid of triglyceride. The result of research is intended to find the best design of obstacle to be used in the column reactor in order to increase the reaction rate of biodiesel production.

2.0 MODELING METHOD

Base on our previous paper (Wulandani *et.al*, 2011) we have chosen the volume of fraction (VOF) approach of CFD simulation for modeling methanol bubble behavior in the triglyceride within column reactor. In the present paper, we focus on flows through internals where liquid (triglyceride) and gas (methanol) strongly interact but without interpenetrating. We neglected the diffusivity of gas into liquid and the reaction between two phase fluids. The VOF model be able computing two phase flows where the phases do not mix, i.e. the gas-liquid interface is clearly identified (Raynal and Hartel, 2001).

Two types of software are implemented to compute the CFD simulation; Gambit 2.4.6 as pre processor where the geometry of reactor is drawn, and Fluent 13.0.0 ANSYS 13 as processor and post processor. Figure 1 depicts configuration of column reactor without obstacle and the mesh structure. Dimension of column reactor is 192 mm height and 55 mm diameter. Methanol gas kept on mass flow rate of 4 g/min (or 6.00e-05 kg/s) is introduced from the bottom of reactor through height of inlet pipe of 45 cm and diameter of 4.8 mm. Outlet diameter is 10.5 mm and height of 25 cm. Liquid of oil (triglyceride) height is 138.6 mm from the bottom of reactor (equivalent of 250 g oil). The grid consist several types of mesh, i.e. hexagon and tetrahedral shape and several combinations of mesh interval; 1 mm, 2 mm, 3 mm and 4 mm. CFD modeling have been performed on three-dimensional and time dependent analysis. Two-phase fluids turbulence has been included using standard k-ε model. The number of iteration is 60 per time step. The time step is 5 x10^{-5} s and there is 3 x 10^4 times step used to execute the simulation in order to obtain 1.5 s real time of bubble flow, while the corresponding computational time is about 6 x 24 hours. A set computer processor Intel® core ™ i5 CPU, 3.33 GHz and RAM of 8 Gb was utilized to make calculations. The thermal-physical property of materials is described in Table 1.

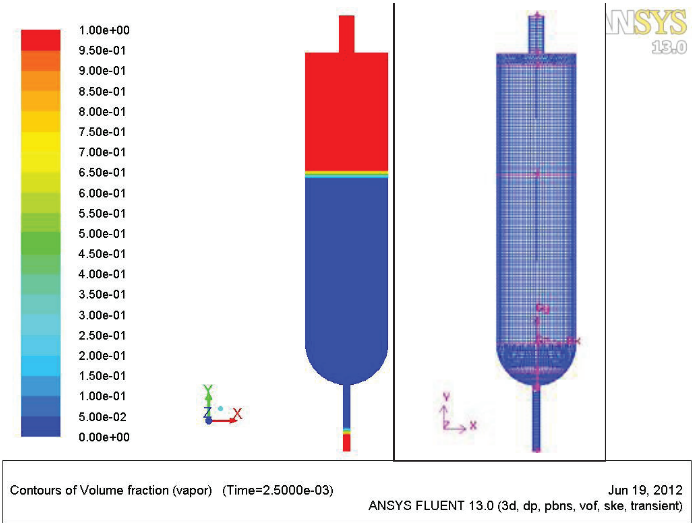

FIGURE 1.
Configuration of column reactor model and mesh structure

TABLE 1.
The thermal and physical properties of materials

No.	Material	Density (kg/m^3)	Viscosity (Pa.s)	Surface tension (N/m)
1.	Methanol (At T = 290°C)	0.693	1.873E-05[1]	
2.	Triglyceride (At T = 290°C)	807.8[2]	1.32e-05[3]	0.01628[4]

1. Teske *et.al.* (2006)
2. Coupland *at.al.* (1997)
3. Rabelo *at.al.* (2000)
4. Chumpitaz *et.al.* (1999)

There are nine types of obstacle be simulated within the column reactor. The configurations of model are described below.

S type is column reactor without obstacle.
N1 obstacle type is perforated cylindrical with 20 mm of diameter and height of 20 mm, consists 9 holes (4 mm holes diameter) on the side of cylinder placed on the bottom of reactor.

N2 obstacle type is perforated cylindrical with 20 mm of diameter and height of 10 mm, consists 9 holes (4 mm holes diameter) on the side of cylinder placed on the bottom of reactor type is perforated cylindrical with 2 mm of diameter 9 holes on the side of cylinder placed on the bottom of reactor.

N3 obstacle type is perforated cylindrical with 20 mm of diameter and height of 10 mm, consists 9 holes on the side of cylinder and addition of 6 holes on the surface of cylinder (4 mm of holes diameter) placed on the bottom of reactor.
DO7 obstacle type is the obstacle consists of cylinder (height of 220 mm and diameter of 42 mm) and double perforate plate (7 mm pitch, 24 holes, 4 mm diameter) installed inside.

N2+DO7 obstacle type is combination of N2 type and DO7 type.
A1 obstacle type is a single pivot installed with four different perforate plates. The distance among perforated plates is 60 mm, respectively.
A2 obstacle type is a pivot installed with three different perforate plates. The distance among perforated plates is 60 mm, respectively.
A3 obstacle type is a pivot installed with three different perforate plates. The distance among perforated plates is 50 mm, respectively.

3.0 RESULT AND DISCUSSION

3.1 Contact Surface Area and Gas Holdup

Contact surface area is the surface area where methanol gas adheres to liquid of triglyceride. In the CFD simulation the area is determined by calculate the area when the value of volume fraction of methanol and triglyceride are 0.5 respectively. The influence of several types of obstacle utilization within the column reactor to the contact surface area is shown in Figure 2. From that figure, utilization of obstacle is proven to increase the contact surface area significantly. This result is in analogy to the previous research (Wulandani *et.al*, 2011).

N1, N2 and N3 type utilization do not yield a substantial increase in contact surface area when it is compared to the other. It can be explained by Figure 3, where methanol gas restrained in the cylinder before it is break out, resulted the degradation gas velocity. The bubble flow up towards the edge of reactor and some of them adhere on the wall.

Furthermore, the DO7 type and the combination between N2 and DO7 type are able increase the contact surface area in comparison with N1, N2 and N3 type. There is no significant difference of contact surface area between DO7 and N2+DO7 type. Setting up the perforate plate inside the cylinder restrain the bubble flow up, in consequently bubble flow towards the edge and then circulated along the height of cylinder. Presence of cylinder generates circulation flow of bubble, in same time it gives the effect increasing of bubble number and increasing of contact surface area. However, bubble flow towards near the wall, which result decreasing of contact surface area due to the methanol gas does not contact to liquid instead of the wall.

Base on the above result, the next CFD simulation does not use the N type of obstacle anymore. Utilization of A1, A2 and A3 improve the contact surface area significantly about 3.25 times of that of S type (without obstacle). However there is no significant difference of contact surface area among of them as shown the graphs which coincide to each other. A number of little bubbles which appear and flow up through plate perforate installed on the single pivot increase the contact surface area.

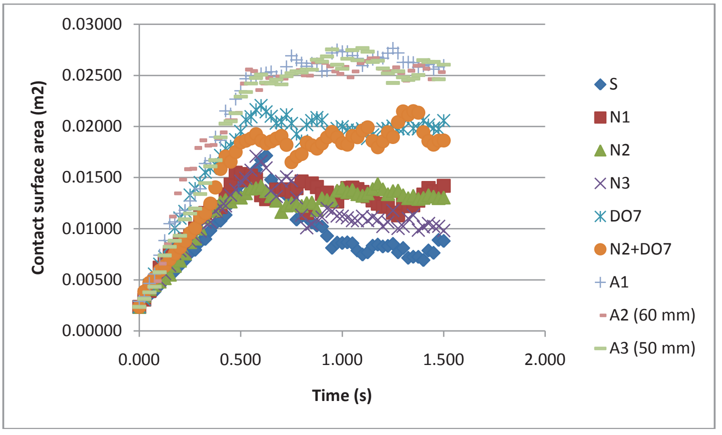

FIGURE 2
Contact surface area between methanol and triglyceride within column reactor versus time at several types of obstacle

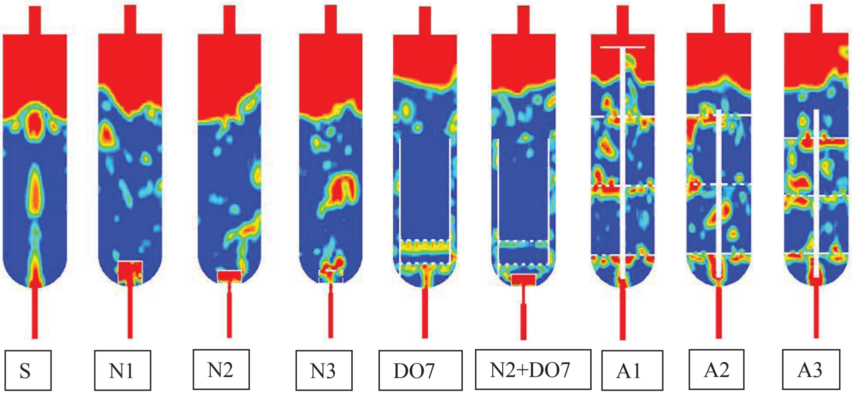

FIGURE 3
The methanol bubble behavior of CFD simulation result at several types model of obstacle

Gas holdup is defined as the fraction of gas volume in an aerated gas-liquid dispersion, i.e., gas plus liquid (Yang and Wang, 1991). The parameter is very important to describe the interaction between two-phase fluid flow in the column reactor. The Figure 4 shows the gas holdup at several types of obstacle utilization within the column reactor. The graphs have similar tendency with those in Figure 2; both of them result that A1 type performs a number little bubble and gives the highest gas holdup value and the highest contact surface area of 0.026 m2, 0.225 %, respectively. This seems to imply that the dimension of bubble decreases and contact surface area increases with increasing gas holdup. The result is in agreement with other group researcher (Letzel, *et.al*. 1999; Wang, *et.al*, 2003).

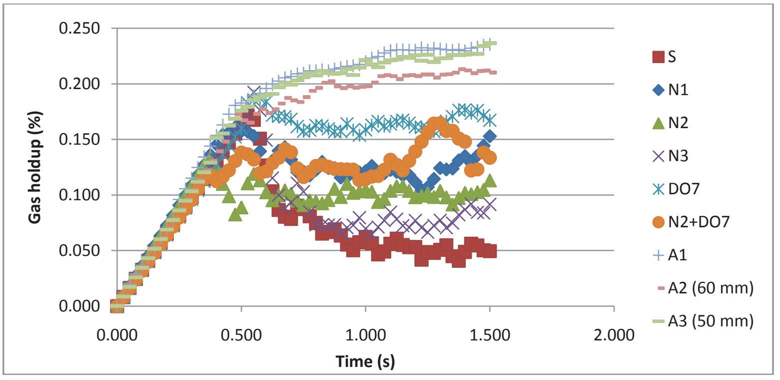

FIGURE 4
Gas holdup within column reactor versus time at several types of obstacle

3.2 Residence Time

Residence time is defined as the average amount of time that a particle spends in particular system. The higher time of contact between methanol gas and triglyceride is the higher of biodiesel producing. Figure 5 depicts the residence time of several obstacle types. N types yield some little bubble which flow up without significant obstacle (Figure 3). Even though there are some little bubble rises, the bubble flow up to the surface immediately, therefore decreasing of contact time bubble in the liquid.

In case of DO7 type, bubble which is circulated through the bottom of cylinder towards the surface along the edge of reactor could increase the contact time of bubble in the liquid before it break up to the surface (Figure 3). A2 type yields the highest residence time of bubble than the others. The residence time value of A2 type is slightly different from A1 type of 0.406 s and 0.357 s. Moreover, A1 type result the higher contact surface area and gas holdup than those of A2. Configuration of single pivot with perforated plate installed could resist the bubble longer than other types did.

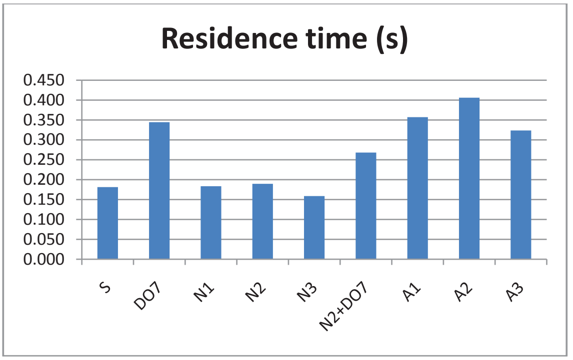

FIGURE 4
Residence time of bubble of several types of obstacle

4.0 CONCLUSION

The computational investigation has shown that the utilization of obstacle significantly increases the contact surface area, gas holdup and residence time which is explained by the behavior of bubble in the liquid. Utilization of single pivot consists three perforated plate within the column reactor has given the highest mean value of contact surface area, gas holdup and residence time of 0.026 m2, 0.225 % and 0.357 s, respectively. The alteration of distance among of perforated plates within the column reactor have no significant effect to the parameter of contact surface area, gas holdup and residence time.

5.0 ACKNOWLEDGEMENT

We would like to thank to United Nation University (UNU) for funding the research. This research which is a follow-up research of the UNU-Kirin Fellowship Programme at the National Food Research Institute, Tsukuba, Ibaraki, Japan in 2010-2011, is supported by Kirin Holdings Co., Ltd., Tokyo, Japan.

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