Effects of Reaction Temperature and Inlet Velocity of a Bubble Column Reactor on the Bubble Size for Biodiesel Production

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Abstract. Bubble column reactors (BCR) are multiphase reactors used in the production of biodiesel. A bubble column reactor can withstand a higher temperature and provide higher efficiency in the process. During the transesterification process in the bubble column reactor, the bubble will be produced and will affect the bubble column reactor performance in biodiesel production. This study aimed to determine the effects of various reaction temperature and inlet velocity in a bubble column reactor on the sizes of the bubble for the transesterification reaction in the production of biodiesel. Different design of perforated plate is also used to find the effects of bubble size. The temperature used are 523 K, 543 K and 563 K and the inlet velocity are 2 m/s, 4 m/s and 6 m/s, respectively. Design and simulation of BCR were performed using SOLIDWORK 2018 ANSYS Fluent. The results obtained show that a drastic changing of gas holdup was found for design *A* at 563 K and 6 m/s inlet velocity. On the other hand, high circulation pattern occurred on the inlet, outlet, holes of perforated plate, and wall of reactor.

Keywords: Bubble column reactor · Biodiesel · Computational fluid dynamics · Gas holdup

1 Introduction

Nowadays, the production of biodiesel occurs in the gas-liquid reactor to produce biodiesel. To define a correct choice of reactors to be used, optimum pressure, temperature of reaction and production size are the factors that need to be considered. In general, any reactor types should provide appropriate residence time, heat exchange, and mass transfer for efficient product formation [1].

Bubble column reactors are preferred as it can be used for conducting a variety of two phase and three phase reactions. Some advantages of bubble column reactors are they have excellent heat and mass transfer characteristics, require little maintenance, and have low operating cost. For bubble columns to work efficiently, several conditions must be complied. These working conditions include temperature, pressure, superficial gas velocity, velocity magnitude and fluid flow pattern. To analyze and solve problems that involves fluid flows, computational fluid dynamics (CFD) can be used to achieve

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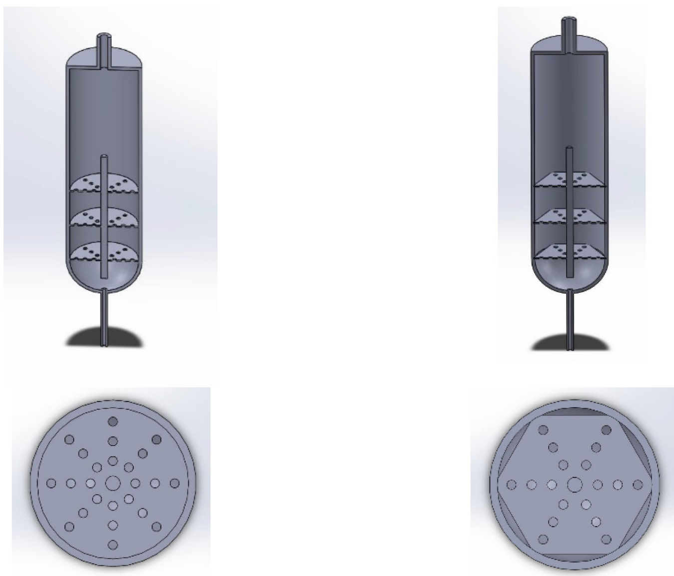
this objective. CFD analysis uses numerical analysis and data structures to perform calculations required to fabricate the simulation of the flow of the fluid, along with its interactions and constraints. The simulation of CFD acts as a convenient tool for predicting process characteristics and their dependence on design and operating variables [2]. This study aimed to determine the effects of different reaction temperature and inlet velocity on the bubble size of transesterification reaction mixture in bubble column reactor. For simulation, it focuses on different perforated plate column design.

2 Methodology

Two different designs of the bubble column reactor were suggested based on previous work [3]. The perforated plate inside the bubble column reactor for Design *A* is circular shaped, while for Design *B*, the perforated plate is hexagonal shaped. Figure 1 shows the cross-sectional view and the top view of the plate for both designs.



Design *A* Design *B*

Fig. 1. Cross sectional view of design *A* and *B*.

2.1 CFD Simulation

Boundary conditions are compulsory constraints for the solution of a boundary value problem. The inlet boundary condition was set up as the mixture of methanol vapor and triglyceride, with a set of inlet velocity of 2 m/s, 4 m/s, and 6 m/s while the outlet boundary condition as pressure boundary condition, was set at 100 kPa (atmospheric pressure). The backflow oil volume fraction value at outlet was set to one. Wall boundary condition for vapor wall and liquid wall was set as stationary wall and no slip wall. The properties of materials and boundary conditions used in the flow analysis were summarized in Table 1 and 2, respectively.

Table 1. Properties of materials.

Properties	Air	Methyl alcohol vapour	Palm oil
Density (kg/m^3)	1.225	1.43	909
C_p (Specific Heat) (J/kg-K)	1006.43	‘ – ‘	281.0665
Thermal conductivity (W/m-K)	0.0242	0.0163	0.1041
Viscosity (kg/m-s)	1.7894e − 05	1.35e − 05	0.069
Molecular weight (kg/kmol)	28.966	32.04	885.4321
Standard state enthalpy (J/kgmol)	‘ – ‘	−2.01097e + 08	−2.056e + 09
Reference temperature (K)	298.15	298.15	298.15

Table 2. Boundary condition used in fluid domain.

Boundary condition	Value
Inlet Velocity (m/s)	2, 4, 6
Pressure (kPa)	100
Temperature (K)	523–563 in 20 K interval
Multiphase	Volume of Fluid
Turbulence	k-epsilon
Wall	No-slip

3 Results and Discussions

3.1 Results on Gas Holdup

Gas holdup is an important characteristic to determine the effect of velocity and temperature on reaction rate. The value of gas holdup was defined as the volume fraction of methanol gas in the total volume mixture of triglyceride and methanol vapor in the reactor which is obtained from this simulation. Gas holdup is related to the bubble sizes and velocity. Therefore, the increase of the velocity and temperature will give an increase in the value of gas holdup, which could affect the bubble sizes in the bubble column reactor. The results of the gas holdup at 523 K for Design *A* are shown in Fig. 2.

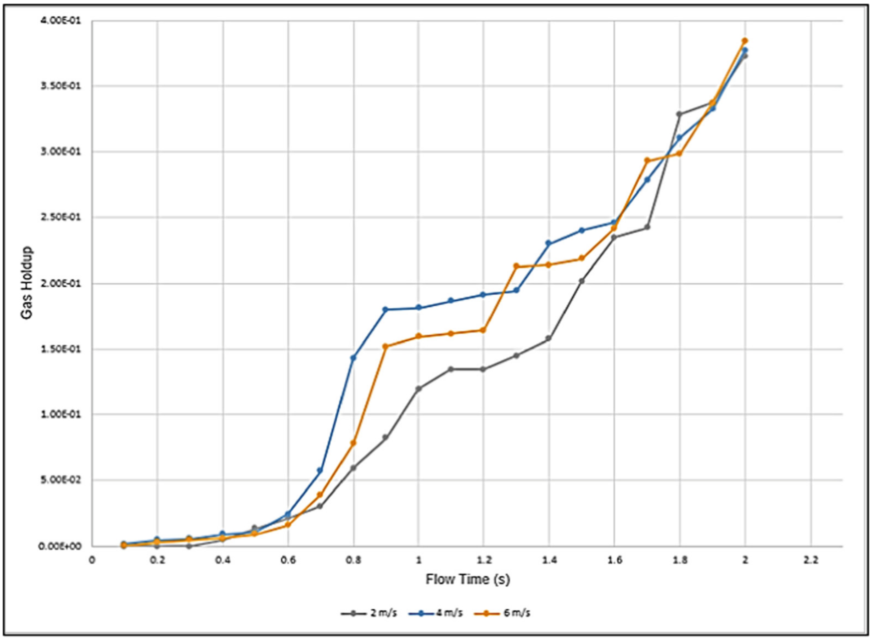


Fig. 2. Gas holdup versus flow time for 523 K for Design *A*.

4 Conclusion

In conclusion, the bubble sizes were obtained based on the value of gas holdup which referring the vapor volume fraction in volume mixture in the bubble column reactor. The increase of the inlet velocity in the simulation produced the increasing value of gas holdup. The higher value of gas holdup produced the small bubble size in the reactor while the large bubble sizes occur when the decreases value gas holdup. The value of gas holdup shown for Design *A* was increasing when temperature and inlet velocity increase. The value of gas holdup obtained from Design *B* shows constant value for the whole flow time and this suggest that the design of perforated plate need modification with other parameters.

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