Influence of heat removal using fine bubbles

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Abstract. Cooling towers are necessary units used to cool down hot water from industrial processes. These units use high air volume metric flow rate and make up water. These are the disadvantages of using cooling towers. This research applied bubbling technique to cool down hot water. The bubble column was used in this study at different air flow rate. Hot water filled in the column was set at 40\textdegree{}C. Water loss and the reduction of temperature of water were observed. The results showed that the highest evaporation rate of water and the shortest of bubbling time were observed at the highest air flow rate. On the other hand, the lowest amount of air used was observed at the lowest of air flow rate which is the optimum condition of this study. In addition, the rate of heat transfer increases when the turbulent flow in the bubble column was formed.

1. Introduction

Cooling towers are currently used to cool down hot water from industrial processes. The primary task of using cooling towers is to reject heat from hot water into air. Cold water is then sent back to heat exchangers or to other units for further used. Cooling towers represent a relatively inexpensive of removing low-grade heat from cooling water. However, this system normally uses high air volume metric flow rate resulting in the loss of water. In addition, the use of high air volume flow rate causes fouling and algae bloom on the packing of cooling towers resulting in low efficiency of heat exchangers [1-3].

A bubble column is the general class of multiphase flow i.e., gas and liquid phase. It is normally employed in chemical processes involving reactions such as oxidation, chlorination, polymerization and hydrogenation, and in biochemical processes such as fermentation and biological wastewater treatment and used for mixing in the process of biodiesel production by non-reactive gas mixed [4-8]. Fine bubble technology was used in active gas with the ozone for esterification, the ozonolysis breaks carbon–carbon double bonds into aldehydes and carboxylic acids [4].

To overcome these drawbacks, the bubble column was used to cool down hot water. The rise of bubbles increases the mixing efficiency. In addition, the advantage of fine bubbles is the surface area to volume ratio [9]. This means that smaller bubbles have higher surface area than larger bubble at the same volume. So, fine bubbles might be utilized in the process that large surface area between gas phase and liquid phase are needed. Basically, the bubble column is a cylindrical vessel with a gas
distributor placed at the bottom as illustrated in the figure 1. The bubble column has high heat and mass transfer coefficients and needs low maintenance and operating costs due to lack of moving parts and compactness [9-10]. This can increase heat and mass transfer during the operation.

In this work, fine bubbles were used in the bubble column for cooling hot water. The effects of air flow rate and bubble size were studied.

Figure 1. Bubble column.

2. Methodology
Experiments were carried out in a cylindrical glass bubble column with a diameter and height of 5 cm and 30 cm, respectively, as shown in figure 1. The gas distributor is a perforated ceramic plate with a pore size of 10-16 µm. All experiments were performed in batch mode with 25 cm of water height. Dry air was fed from an air compressor connected with air filter. Flow rates of air were controlled by a flow meter and varied from 3 l/min, 5 l/min, 7 l/min, and 9 l/min to form fine bubbles with diameter of 1-3 mm. The inlet pressure was set at 0.5 barg. The bubble column was operated under atmospheric pressure. The inlet temperature of air was performed at 29°C. The initial temperature of hot water in the bubble column was also set at 40°C as shown in figure 2. Temperature and volume of water in the column were recorded every minute.

Figure 2. Process flow diagram.
3. Results and discussion
The results showed that the bubble size depends on volume metric flow rate of air as shown in figure 3. The biggest size of bubble was observed at the flow rate of 9 l/min, while the smallest one was found at the flow rate of 3 l/min according to the work done by Kantarci and co-workers [10]. The flow regimes located in the bubble column is the homogeneous regime that the gas-liquid mass transfer coefficient is higher than the heterogeneous regime. For homogeneous regime, the superficial as velocity is low, resulting in the formation of small bubble size. A uniform bubble distribution was therefore observed over the entire cross-sectional area of the column. Moreover, the gas hold up of this regime proportionally increases with the superficial gas velocity.

The reduction of temperature of water at different air flow rates was shown in figure 4. Operating times were recorded at temperature of 35°C. The results showed that temperature of water decreased from 40°C to 35°C after 21 minutes without bubbling air. For the air flow rate of 3 l/min, 5 l/min, 7 l/min and 9 l/min, the operating times used to reduce the temperature of water to 35°C are 8 min, 7 min, 5 min and 4 min respectively. This means that the shortest time was detected at the highest flow rate and heat transfer coefficient increases with increasing superficial gas velocity or bubble size [10]. The water loss during the bubbling process at different air flow rate was illustrated in figure 5. The highest evaporation rate of water was found at the air flow rate of 9 l/min with 1.8 ml. This is because the effect of turbulent flow at 9 l/min. However, at high flow rate, a plenty air was used resulting in the increase of operating cost as shown in figure 6. Although, longer operating time was observed at the flow rate of 3 l/min, the water loss and volume of air used is smaller. Therefore, the optimum conditions used in this study is at the smallest bubble size with the air flow rate of 3 l/min.

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Figure 5. Water loss at different air flow rate.

Figure 6. Volume of air used at different air flow rate.

4. Conclusion
The reduction of temperature of water was found during bubbling of air in the bubble column. The shortest bubbling time and the highest evaporation rate of water were observed at the highest bubble size. However, the lowest amount of air used was detected at the air flow rate of 3 l/min, which is the optimum condition of this study. Moreover, the turbulent flow in the bubble column can increase the rate of heat transfer that might be applied this technique in the industry.

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