CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In this work, continuous froth flotation was applied to remove emulsified oil from dilute oily wastewaters as an alternative for industrial wastewater treatment in a large quantity. From the previous work, it was revealed that the interfacial tension (IFT) which is one characteristic of Winsor Type III microemulsion was an important parameter, affecting oil removal. Later, both foamability and foam stability were found to be dominant factors, governing the oil separation efficiency. In most studies, froth flotation was operated in a batch mode, whereas large quantities of industrial wastewater are more efficiently treated by continuous, steady-state processes. Therefore, in the present work, a continuous froth flotation process was developed for treating oily wastewaters. Moreover, foam characteristics were also studied in order to explain the froth flotation results. From the results, the foamability and foam stability of the diesel oil system in the continuous froth flotation unit, $C_{14-15}(PO)_5SO_4Na$ was found to be very poor to produce stable froth. In order to enhance both foamability and foam stability in the flotation column for the successful separation, sodium dodecyl sulfate (SDS) was added as a foam booster. The performance of the continuous froth flotation unit was not significantly affected by changing the oil-to-water ratio in the feed. This suggests that the robustness to a wide range of oil-to-water ratio of the continuous froth flotation is very useful to apply for real wastewater streams. An increase in foam height resulted in increasing the enrichment ratio of diesel oil. However, if the foam height was too high, the generated froth could not reach the outlet and so no separation occurred. The resulted showed that the longer the residence time of the solution in the column, the higher the oil removal efficiency. Under the optimal conditions: 0.1 wt.% $C_{14-15}(PO)_5SO_4Na$, 0.5 wt.% SDS, 4 wt.% NaCl, an oil-to-water ratio of 1:19, a foam height of 26 cm, an air flow rate of 0.25 L/min, and an HRT of 60 min, a maximum diesel oil removal of 96% was achieved.

For the second part to replace SDS for the enhancement of foamability and foam stability, colloidal gas aphron (CGA) was applied to the feed solution before introducing to the froth flotation column. In the CGA experiments, the effects of salinity, surfactant concentration, stirring speed, and stirring time were studied systematically. The optimum conditions of the CGA formation was used to prepare the feed solution for the batch froth flotation experiments. From the results, the maximum diesel oil removal of 97% was obtained at an air flow rate of 0.30 l/min under a non-equilibrium feed with the CGA formation at 0.1 wt.% $C_{14-15}(PO)_5SO_4Na$, 3 wt.% NaCl with a stirring speed of 5,000 rpm and a stirring time of 5 min. The equilibrium feed condition with the CGA had a negative effect on the froth flotation performance as compared to the non-equilibrium feed condition with CGA, this is also consistent with the results in the batch froth flotation in the induced-equilibrium system from the previous work (Yanatatsaneejit, 2004). In addition, in the CGA study, bubble diameters of CGA were measured to find the correlation with the oil removal efficiency. It was found that froth formation and froth stability play an important role in the removal of diesel and surfactant more than the air bubble diameter effect.

6.2 Recommendations

There are several aspects involving froth flotation to be required to clarify. The recommendations for future work are as follows:

1) To study the foam characteristics; for example, how fast foams form. And, the factors which affect the foam formation should be elucidated. The $(d\gamma_t/dt)_{max}$ which can be calculated from the dynamic surface tension results can tell how easier of foam formation because it correlates with the dynamic adsorption of the surfactant on the bubble interface. It is hypothesized that the faster the surfactant adsorption (higher $(d\gamma_t/dt)_{max}$ value), the easier the foam formation.

2) To investigate the dynamic IFT, because the time of the surfactant solution stay in the continuous froth flotation column is shorter than the real time for the system to reach the equilibrium state. Therefore, the dynamic IFT should be measured to compare with the equilibrium IFT of the same solution system in order to correlate the dynamic IFT results to the oil removal efficiency of continuous froth flotation.
3) To improve the mixing (or back-mixing) of bubbles in the column, it is interesting to develop the froth flotation column design by using a multiple-loop flotation column which can provide proper hydrodynamic conditions that will result in higher separation efficiency. A static mixer should be installed in a froth flotation column. The static mixer will improve the mixing and generate the fine bubble, resulting in increasing the specific interfacial area of air bubbles.
4) To develop a multi-stage froth flotation in order to improve the separation efficiency by using the similarity to multistage foam fractionation.