WIND TUNNEL AND OPEN CHANNEL FOR AMMONIA REMOVAL FROM SKIM LATEX: PART II. MODELING AND SYSTEM DESIGN

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Abstract: *The research was aim to investigate the ammonia removal from skim latex using new approach, the wind tunnel. The overall mass transfer coefficient as a function of operating parameters were experimentaly determined. The design equation for the wind tunnel were developed from general mole balance equation and verified against the experimental data. The design equations can use to design operating condition and the length of the wind tunnel that gave the desire ammonia removal. The length of the wind tunnel required to remove NH_3 to any lavel were 1.8- 2.8 time shorter than that of the conventional approach, the open channel flow, depending on an applied air velocity. It can be concluded that the wind tunnel approach is a promising mean for ammonia removal from skim latex.*

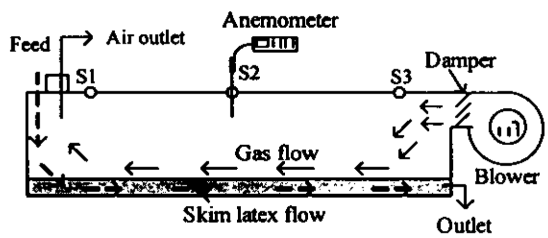
Key Words: ***Wind Tunnel / Ammonia Removal/Skim Latex/ Open Channel***

1. INTRODUCTION

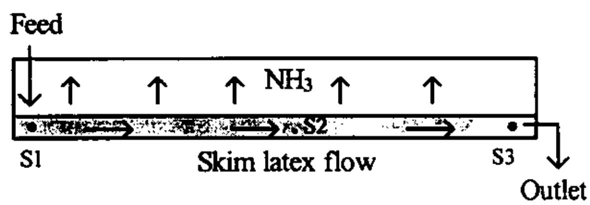
The removal of ammonia (NH_3) from skim latex is an essentail step in production of skim rubber sheet. The concentration of NH_3 in skim latex ranges from 0.2 to 0.5 % by weight. The presence of NH_3 in skim latex resulting in high consumption of acid used in coacolation of skim rubber, consequencely NH_3 needs to be removed from skim latex before rubber coaculation step. In the old day, the NH_3 is removed from the skim latex using the open channel flow which required quite large area and high construction cost. To overcome this problem, this research proposes the new approach for removing NH_3 from skim latex using the wind tunnel. The design information and the performance of the wind tunnel as compared to the conventional system are presented in this work.

2. EXPERIMENTAL AND PROCEDURE

The experiments for ammonia removal from skim latex was perfromed using existing industrial size open channel flow and newly constructed wind tunnel at concentrated latex rubber industry located in Songkhla province Thailand. The open channel flow was 80 m long, 0.9 m wide and 0.1 m heigh. The wind tunnel system composes of the flow channel, 80 m long, 0.9 m wide and 0.1 m heigh, coverred with wind tunnel 80 m long, 0.9 m wide and 0.1 m heigh. The wind tunnel and the open channel flow used in this study are diagrammatically shown in Figure 1a and 1b, respectively.



(a) Wind tunnel



(b) Channel flow

Figure 1 Diagram of the wind tunnel and the open channel flow system

The experimental procedures and conditions for NH_3 removal investigation for both wind tunnel and open channel flow at various conditions were deatiled elswhere [1]. The overall mass transfer coefficients and the design equation for both wind tunnel and the open channel were developed and discussed here in.

3. RESULTS AND DISCUSSION

3.1. General mass balance equation

General mass balabce equations for NH_3 removal from channel flow with and without wind tunnel are the same and can be expressed as given by equation (1).

$$Q_{in}C_{NH_3,in} - Q_{out}C_{NH_3,out} - K_{OL}AC_{NH_3,avg.} = \frac{dN_{NH_3}}{dt} \quad (1)$$

At steady state, $\frac{dN_{NH_3}}{dt} = 0$, with constant volumetric flow rate, $Q_{in} = Q_{out} = Q$, equation (1) reduces to

$$K_{OL}A = \frac{Q(C_{NH_3,in} - C_{NH_3,out})}{C_{NH_3,avg.}} \quad (2)$$

or in dimensionless term

$$K^*_{OL} = \frac{K_{OL}A}{Q} = \frac{(C_{NH_3,in} - C_{NH_3,out})}{C_{NH_3,avg.}} \quad (3)$$

From equation (3), one can obtain the mass transfer coefficient K_{OL},in m/s, as given by equation (4).

$$K_{OL} = \frac{K^*_{OL}Q}{A} \text{ or } \frac{K^*_{OL}}{K_{OL}} = \frac{Q}{A} \quad (4)$$

Where the Q/A can be determined from the dimension of the channel and the liquid velocity as expressed by equation (5)

$$\frac{A}{Q} = \frac{L}{U_L h_L} \text{ or } L = \frac{U h_L A}{Q} \quad (5)$$

Equations (2) to (5) are the design equations that can be used to determine the operating conditions such as air velocity (U_G), liquid velocity (U_L), liquid height (h_L) and the length (L) of the wind tunnel or open channel flow which required to remove NH_3 from skim latex to a required level. To utilize these equations, the mass transfer coefficients (K^*_{OL} and K_{OL}) for NH_3 removal from both wind tunnel and open channel flow are required.

3.2. Mass transfer coefficients, (K^*_{OL} and K_{OL})

The K^*_{OL} for NH_3 removal using the wind tunnel can be determined from measured inlet and outlet NH_3 concentration as detailed by equation (3). Once the K^*_{OL} is known, the K_{OL} can be calculated according to equation (4). The relationship between K^*_{OL}, K_{OL} and R_e that characterized the air flow in the wind tunnel are shown in figure 2 and 3.

From these figures, the linear relationship between mass transfer coefficient and R_e was observed and can be expressed by equation (6) and (7) for K^*_{OL} and K_{OL}, respectively.

$$K^*_{OL} = 3.095\times10^{-6}\,\text{Re} - 5.819\times10^{-3} \quad (6)$$

$$K_{OL} = 1.161\times10^{-10}\,\text{Re} - 2.182\times10^{-7} \quad (7)$$

where $R_e = \frac{\rho_{air}U_G R_{hG}}{\mu_G}$

R_{hG} = hydraulic radius of air in the wind tunnel

$$R_{hG} = \frac{Wh_G}{W + 2h_G}$$

where W and h_G are the width and height of the wind tunnel in m, respectively.

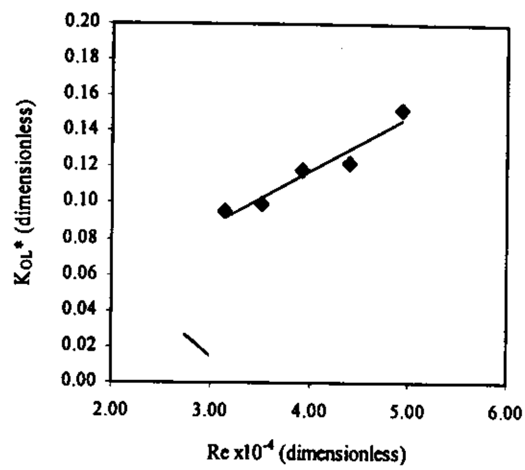


Figure 2 K^*_{OL} vs. R_e for ammonia removal from the wind tunnel (T= 30 °C , U_G = 3.9-6.1 m/s and U_L = 0.1 m/s)

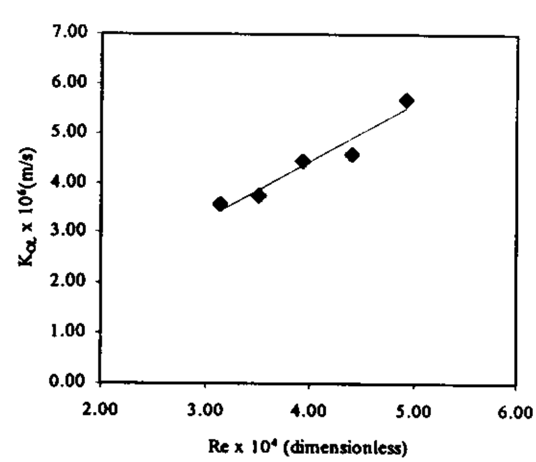


Figure 3 K_{OL} vs. R_e for ammonia removal from the wind tunnel (T= 30 °C , U_G = 3.9-6.1 m/s and U_L = 0.1 m/s)

The $K_{OL}^{\bullet}$ and K_{OL} for open channel flow were determined using the same procedure as detailed for the wind tunnel. However, in case of the open channel flow, the wind speed over the skim latex is approximately zero, thus the R_{eL} characterized the water flow was used instead of R_e. The relationship between $K_{OL}^{\bullet}$, K_{OL} and R_{eL} are expressed as equations (8) and (9).

$$K_{OL}^{\bullet} = 2.668\times10^{-1} - 5.401\times10^{-5}\,\mathrm{Re}_L \qquad (8)$$

$$K_{OL} = 7.674\times10^{-6} - 1.288\times10^{-9}\,\mathrm{Re}_L \qquad (9)$$

where $R_{eL} = \dfrac{\rho_{water} U_L R_{hL}}{\mu_L}$

R_{hL} = hydraulic radius of water in the channel

$$R_{hL} = \frac{Wh_L}{W + 2h_L}$$

where W and h_L are the width and height of liquid in channel (in meter), respectively.

3.3 Wind tunnel and open channel flow design

From the design equations and the mass transfer coefficient correlations of the wind tunnel and the open channel flow system, as previously detailed. We can calculated two important design parameters, U_G, and L, required to remove NH_3 from skim latex to a desired level using the wind tunnel or open channel system. The concentrations of NH_3 in skim latex fed to system were varied from 0.1 to 0.4 % by weight. The skim latex height in channel (h_L) and the skim latex velocity (U_L) are constant at 3 cm and 0.1 m/s. The desired NH_3 concentrations in outlet stream of the skim latex are considered in four levels including 0.25, 0.2, 0.15 and 0.1 % by weight. The relationship between U_G, L and the inlet NH_3 concentration that gave the outlet NH_3 concentration of 0.25, 0.2, 0.15 and 0.1 % by weight are shown in figure 4, 5, 6, and 7, respectively. From these figures, one can determine the air velocity, the length of the wind tunnel and the length of open channel flow which can remove NH_3 in skim latex down to any required level.

3.4 The comparison of the wind tunnel and the open channel flow

It can be seen from figures 4 to 7 that, at the same condition, the open channel required the longer length than the wind tunnel. The ratios of the length of the open channel to the length of the wind tunnel do not depend upon the inlet NH_3 concentration but it strongly depend on air velocity as typically depicted in figure 8.

From the result indicating that the length of the wind tunnel required to remove NH_3 to any level were 1.8- 2.8 time shorter than that of the conventional approach, the open channel flow.

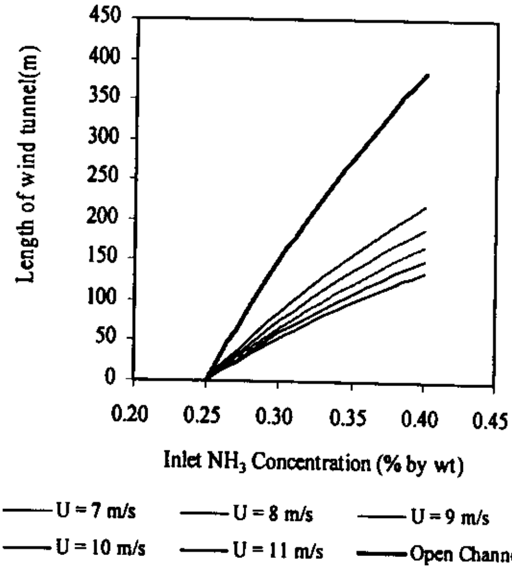


Figure 4 Length of the wind tunnel and open channel required to obtain 0.25% ammonia remaining in skim latex for various inlet NH_3 concentrations (T= 30 °C, U_G = 7-11 m/s and U_L = 0.1 m/s)

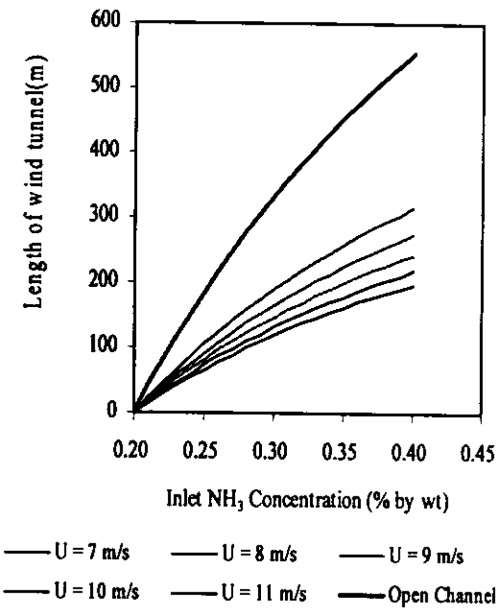


Figure 5 Length of the wind tunnel and open channel required to obtain 0.20% ammonia remaining in skim latex for various inlet NH_3 concentrations (T= 30 °C, U_G = 7-11 m/s and U_L = 0.1 m/s)

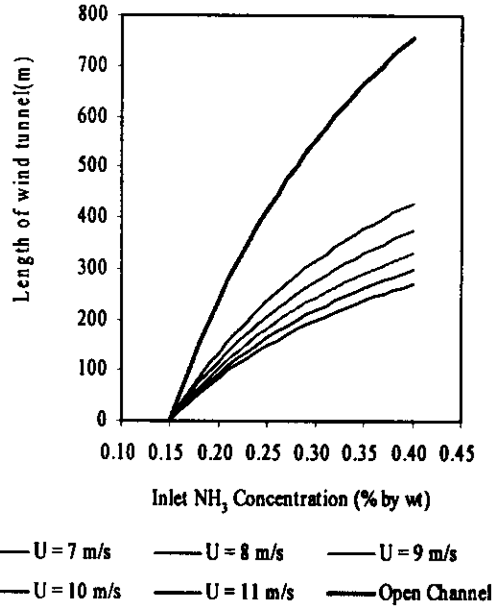


Figure 6 Length of the wind tunnel and open channel required to obtain 0.15% ammonia remaining in skim latex for various inlet NH_3 concentrations (T= 30 °C , U_G = 7-11 m/s and U_L = 0.1 m/s)

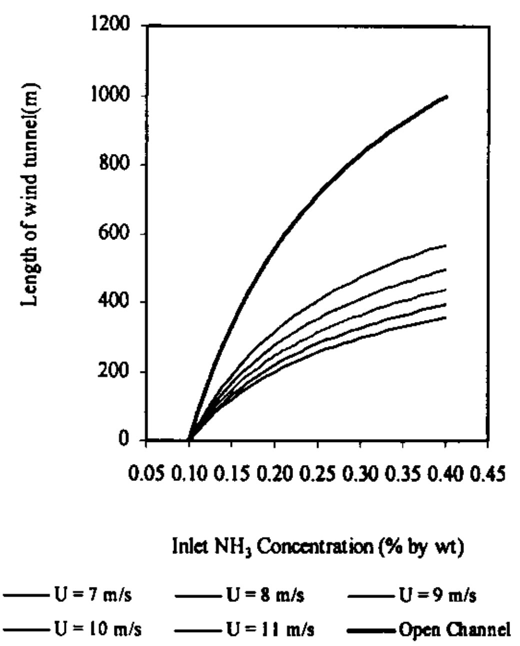


Figure 7 Length of the wind tunnel and open channel required to obtain 0.15% ammonia remaining in skim latex for various inlet NH_3 concentrations (T= 30 °C , U_G = 7-11 m/s and U_L = 0.1 m/s)

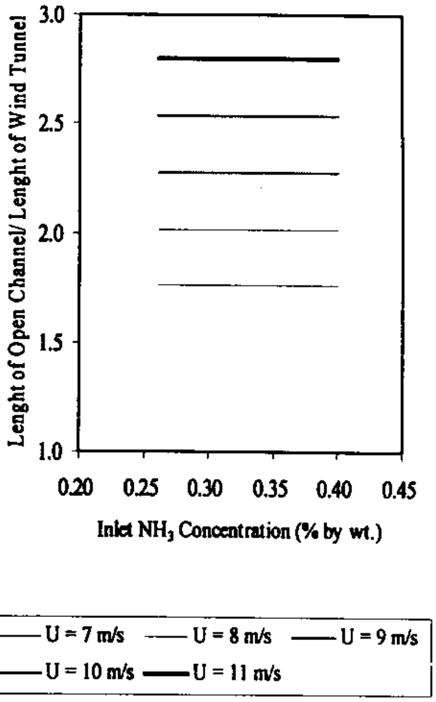


Figure 8 Ratio of Length of the open channel to the length of the wind tunnel to obtain 0.25% ammonia remaining in skim latex for various inlet NH_3 concentrations (T= 30 °C , U_G = 7-11 m/s and U_L = 0.1 m/s)

4. CONCLUSION

This study has proposed a new approach for NH_3 removal from the skim latex. The overall mass transfer coefficient as a function of operating parameters were experimentaly determined. The design equation for the wind tunnel and the open channel flow were developed from general mole balance. The design equations can use to determine the air velocity, the length of the wind tunnel and the length of open channel flow which can remove NH_3 in skim latex down to any level. The length of the wind tunnel required to remove NH_3 to any level were 1.8- 2.8 time shorter than that of the conventional approach, the open channel flow. It can be concluded that the wind tunnel approach is a promising mean for ammonia removal from skim latex.

5. REFERENCES

[1] J. Chungsiriporn , B. Bunyakan, and J. Intamanee, "Wind Tunnel and Open Channel for Ammonia Removal from Skim Latex: Part I. Experimental and Removal Determination". Paper submitted to present at PSU-UNS International Conference on Engineering and Environemt-2007 (ICEE-2003) 10-11 May 2007. Phuket. Thailand.