## LIST OF FIGURES

Figure No Caption Page No
$\begin{array}{lll}\text { Figure 2.1 Flow regimes in bubble columns } & 12\end{array}$
$\begin{array}{lll}\text { Figure } 2.2 \text { Flow regime map } & 12\end{array}$
$\begin{array}{lll}\text { Figure } 2.3 & \text { Dependence of flow regimes on gas velocity } & 13\end{array}$
Figure 2.4 Variation of gas holdup for air-water system estimated using various 27 correlations

Figure 2.5 Variation of interfacial area for air-water system estimated using 42 various correlations

Figure 3.1: (a) Experimental Set-up for bubble column 58
Figure 3.1: (b) Experimental Set-up for Single bubble study 58

Figure 3.2 Photograph of experimental setup 61

Figure 3.3 Calibration of Syringe Pump 63
Figure 4.1(a) A couple of bubbles moving up 68
Figure 4.1(b) Position of bubbles after a lapse of 0.00833 s . 68

Figure 4.2 Bubbles don’t move vertically during Continuous bubbling. 68

Figure 4.3 Acoustic signal for about 0.5 s from the start of signal captured 70

Figure $4.4 \quad$ Acoustic signal for about 0.01 s from the start of signal captured 70

Figure 4.5 Fast Fourier transform of Acoustic signal presented in Figure $4.4 \quad 71$

Figure 4.6 A typical cropped acoustic signal in bubble column at $U_{g}=\quad 74$ $0.00833 \mathrm{~m} \mathrm{~s}^{-1}, Z=0.05 \mathrm{~m}, H_{s}=0.24 \mathrm{~m}$.

Figure $4.7 \quad$ Fourier transform of cropped acoustic sample for $U_{g}=0.0083$
$\mathrm{m} \mathrm{s}^{-1}, Z=0.05 \mathrm{~m}, H_{s}=0.24 \mathrm{~m}$.
Figure 4.8 BSD for distilled water at $U_{g}=0.00833 \mathrm{~m} \mathrm{~s}^{-1}, H_{s}=0.24 \mathrm{~m}$, $Z=0.10 \mathrm{~m}$.

Figure 4.9 Effect of $U_{g}$ on BSD for distilled water at $H_{s}=0.22 \mathrm{~m}, Z=0.00 \mathrm{~m}$.
Figure 4.10 Effect of $U_{g}$ on BSD for distilled water at $H_{s}=0.22 \mathrm{~m}, Z=0.10 \mathrm{~m}$.
Figure 4.11 Effect of $H_{s}$ on BSD for distilled water at $Z=0.00 \mathrm{~m}, U_{g}=0.033$ $\mathrm{ms}^{-1}$.

Figure 4.12 Effect of $H_{s}$ on BSD for distilled water at $Z=0.20 \mathrm{~m}, U_{g}=0.017$ $\mathrm{ms}^{-1}$.

Figure 4.13 Effect of $Z$ on BSD for distilled water at $H_{s}=0.20 \mathrm{~m}, U_{g}=0.042$ $\mathrm{ms}^{-1}$.

Figure 4.14 BSD for $0.5 \%(\mathrm{w} / \mathrm{w})$ ethylene glycol solution at $U_{g}=0.0083 \mathrm{~ms}^{-1}$, $H_{s}=0.15 \mathrm{~m}$ and $\mathrm{Z}=0.00 \mathrm{~m}$.

Figure 4.15 Effect of $U_{g}$ on BSD for $0.5 \%$ EG solution at $H_{s}=0.10 \mathrm{~m}, Z=$ 0.00 m .

Figure 4.16 Effect of $H_{s}$ on BSD for $0.5 \%$ EG solution at $U_{g}=0.111 \mathrm{~ms}^{-1}, Z=$ 0.05 m .

Figure 4.17 Effect of $Z$ on BSD for $0.5 \%$ EG solution at $H_{s}=0.10 \mathrm{~m}, U_{g}=$ $0.139 \mathrm{~ms}^{-1}$.

Figure 4.18 BSD for $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{CMC}$ solution at $U_{g}=0.0417 \mathrm{~ms}^{-1}, H_{s}=0.15$ $m$ and $Z=0.00 \mathrm{~m}$.

Figure 4.19 Effect of $U_{g}$ on BSD for $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{CMC}$ solution at $H_{s}=0.15 \mathrm{~m}$ and $Z=0.05 \mathrm{~m}$.

Figure $4.20 \quad$ Effect of $Z$ on BSD for $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{CMC}$ soln. at $U_{g}=0.083 \mathrm{~ms}^{-1}$
and $H_{s}=0.15 \mathrm{~m}$.

Figure 4.21 Effect of $H_{s}$ on BSD for $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{CMC}$ soln. at $U_{g}=0.104 \mathrm{~ms}^{-1}$
89 and $Z=0.05 \mathrm{~m}$.

Figure 4.22 Effect of conc. on BSD for air/aq. CMC soln. at $U_{g}=0.063 \mathrm{~ms}^{-1}$, $H_{s}=0.20 \mathrm{~m}$ and $Z=0.05 \mathrm{~m}$.

Figure 4.23 BSD for $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{NaOH}$ solution at $U_{g}=0.0625 \mathrm{~ms}^{-1}, H_{s}=0.15$ m and $\mathrm{Z}=0.00 \mathrm{~m}$.

Figure $4.24 \quad$ Effect of $U_{g}$ on BSD for $0.1 \%(w / w) \mathrm{NaOH}$ solution at $H_{s}=0.10$ m and $Z=0.05 \mathrm{~m}$.

Figure 4.25 Effect of $Z$ on BSD for $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{NaOH}$ soln. at $U_{g}=0.0833 \mathrm{~ms}^{-}$ ${ }^{1}$ and $H_{s}=0.20 \mathrm{~m}$.

Figure 4.26

Figure 4.27 Effect of conc. on BSD for air $/ \mathrm{NaOH}$ soln. at $U_{g}=0.0083 \mathrm{~ms}^{-1}$, $H_{s}=0.20 \mathrm{~m}$ and $Z=0.05 \mathrm{~m}$.

Figure $4.28 \quad$ Value of $\sigma$ for air-water system as a function of $U_{g}, H_{s}, Z=0.15 \mathrm{~m}$.

Figure 4.29 Value of $\sigma$ for air-EG solution system as a function of $U_{g}, H_{s}$, $Z=0.15 \mathrm{~m}$.

Figure $4.30 \quad$ Value of $s_{1}$ for air-EG solution system as a function of $U_{g}, H_{s}$, 98 $Z=0.15 \mathrm{~m}$.

Figure 4.31 Value of $\mathrm{k}_{1}$ for air-EG solution as a function of $U_{g}, H_{s}, Z=0.15 \mathrm{~m}$. 99

Figure 4.32 Value of $\sigma$ for air- NaOH solution as a function of $U_{g}, H_{s}, Z=0.15 \mathrm{~m}$. 99

Figure $4.33 \quad$ Value of $\sigma$ for air-CMC solution as a function of $U_{g}, H_{s}, Z=0.05 \mathrm{~m} . \quad 100$

Figure 4.34 Effect of $U_{g}$ and $H_{s}$ on $d_{32}$ for air/water system at $Z=0.10 \mathrm{~m}$.

Figure 4.35 Effect of $U_{g}$ and $Z$ on $d_{32}$ for air/water system at $H_{s}=0.24 \mathrm{~m}$.

Figure $4.36 \quad$ Sauter-mean diameter as a function of $U_{g}$ and $Z$ for air-water and air-ethylene glycol solutions

Figure 4.37 Effect of $H_{s}$ and $U_{g}$ on $d_{32}$ for $5 \%(\mathrm{w} / \mathrm{w})$ ethylene glycol solution at $\mathrm{Z}=0.05 \mathrm{~m}$.

Figure 4.38 Effect of $U_{g}$ and $H_{s}$ on $d_{32}$ for air/ aq. CMC soln. at $Z=0.10 \mathrm{~m}$.

Figure $4.39 \quad$ Effect of $U_{g}$ and $Z$ on $d_{32}$ for air/ $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{CMC}$ at $H_{s}=0.15 \mathrm{~m}$.
Figure 4.40 Effect of $C M C$ conc. on $d_{32}$ at $H_{s}=0.20 \mathrm{~m}$ and $Z=0.05 \mathrm{~m}$. 108
Figure $4.41 \quad$ Variation of $d_{32}$ with $U_{g}$ and $Z$ for $0.1 \%(w / w) \mathrm{NaOH}$ soln. at $H_{s}$ $=0.00 \mathrm{~m}$.

Figure 4.42

Figure $4.43 \quad$ Variation of $d_{32}$ with $U_{g}$ and $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{NaOH}$ soln. at $Z=0.05 \mathrm{~m}$ and $H_{s}=0.15 \mathrm{~m}$.

Figure 4.44 Gas holdup as a function of $U_{g}$ and $H_{s}$ for air-water and air-CMC solutions.

Figure 4.45 : Gas holdup as a function of $U_{g}$ and $H_{s}$ for air-water and airethylene glycol solutions

Figure 4.46

Figure $4.47 \quad$ Values of $\mathrm{a}_{\mathrm{i}}$ for air-water system as a function of $U_{g}$ and $H_{s}$ at $Z$ $=0.15 \mathrm{~m}$.

Figure $4.48 \quad$ Effect of $U_{g}$ and $H_{s}$ on $a_{i}$ for air/ $0.5 \%(\mathrm{w} / \mathrm{w}) \mathrm{CMC}$ soln. at $Z=0.05$ m.

Figure $4.49 \quad:$ Effect of $U_{g}$ and $Z$ on $a_{i}$ for air/ $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{CMC}$ soln. at $H_{s}=0.15$ m.

Figure 4.50 Effect of $U_{g}$ and CMC soln. on $a_{i}$ for air/ $0.1 \%(\mathrm{w} / \mathrm{w})$ at $Z=0.05 \mathrm{~m}$ and $H_{s}=0.20 \mathrm{~m}$.

Figure $4.51 \quad$ Specific interfacial area as a function of $U_{g}$ and $Z$ for air-water and air-ethylene glycol solutions at $H_{s}=0.20 \mathrm{~m}$.

Figure $4.52 \quad$ Variation of $a_{i}$ with $U_{g}$ and $H_{s}$ for $0.1 \%(w / w) \mathrm{NaOH}$ soln. at $Z$ $=0.05 \mathrm{~m}$.

Figure $4.53 \quad$ Variation of $a_{i}$ with $U_{g}$ and $Z$ for $0.1 \%(w / w) \mathrm{NaOH}$ soln. at $H_{s}$ $=0.10 \mathrm{~m}$.

Figure 4.54 Variation of $a_{i}$ with $U_{g}$ and $H_{s}$ for $0.1 \%(w / w) \mathrm{NaOH}$ soln. at $Z$ $=0.05 \mathrm{~m}$.

Figure $4.55 \quad$ Variation of $a_{i}$ with $U_{g}$ and $0.1 \%(\mathrm{w} / \mathrm{w}) \mathrm{NaOH}$ soln. at $\mathrm{Z}=0.05 \mathrm{~m}$ and $H_{s}=0.15 \mathrm{~m}$.

Figure $4.56 \quad$ Variation of $C$ as a function of time.
Figure 4.57 Plot of $\ln \left(\mathrm{C}^{*}-\mathrm{C}\right) /\left(\mathrm{C}^{*}-\mathrm{C}_{0}\right)$ vs $\left(\mathrm{k}_{\mathrm{L}} \mathrm{a}_{\mathrm{i}}\right) \mathrm{t}$.
Figure $4.58 \quad$ Plot of $\left(k_{L} a_{i}\right)$ vs $U_{g}$.
Figure 4.59 Plot of $k_{L} a_{i}(\mathrm{cal})$ vs.$k_{L} a_{i}(\exp )$

