CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In this concluding chapter the main findings of the thesis are summarised as well as some recommendations for future work are discussed. The online, continuous two-phase flow measurement in a co-current bubble column is a standard practice in process industries. The identification of flow pattern and a reliable measurement of void fraction are vital for accurate modelling of two-phase systems. The research endeavour presented in this thesis has investigated these aspects in two-phase air-water bubble column by using two different non-invasive techniques i.e. Electrical Capacitance Tomography (ECT) and differential pressure (ΔP). The main findings of this experimental study are as follows;

i. The value of capacitance was found to be affected by the purity of water. Since the dielectric is made up of the two-phase flow, the fluids and gases. They must be tested carefully in the experimental setup to minimize the corrosion and degradation of media. Degradation of media will cause an increase in conductance which will affect the capacitance readings. Thus, deionized water was used for the calibration of ECT sensor and for future runs.

ii. It has been observed that the bubble flow regime occurs at low to moderate superficial gas velocities in the co-current bubble column. The experimental analysis indicates that in bubbly flow through the column, the gas component flows as discrete bubbles in a liquid.

iii. Physical observations were also taken through the transparent section of the co-current bubble column which generally shows a good agreement with bubble flow regime map for air-water two-phase system.

iv. The bubble sizes in the co-current bubble column of air-water system gradually reduce with the increase in superficial gas velocity. The bubble sizes were in the range of 8 to 9.95 mm having 1 mm orifice diameter at U_{sg} = 1.31 to 3.05 cm/sec.

v. The calibration of ECT sensor shows a symmetry line graph which represents a good calibrated data between air and deionised water as a low and higher calibration.

vi. It is a common practice to use the normalised capacitance data for image reconstruction which is obtained from raw data measurements. When the normalised capacitance obtained using parallel model for air-water two-phase flow; it was found that the normalised values of capacitances are in between the permissible range of 0 and 1.

vii. The 12 electrode sensor is designed by using COMSOL Multiphysics software of two-dimensional model. The simulation of the sensor facilitates the measurement of voltage distribution in the sensing zone. This numerical simulation result when compared with the experimental result validates the measurements. For air filled sensor the relative error percentage between experimental and simulated results was ±15% and for deionised water filled sensor was ±25%.

viii. The application of distribution models by using ECT raw data to get the normalised and measured capacitances was found for different test conditions. The parallel and series model shows the maximum and minimum values for normalised capacitances while Maxwell and combined model always remain in between them.

ix. On comparing the normalised capacitances obtained from distribution models for different electrode combinations such as: adjacent (C_{12}) electrodes, one –

adjacent (C_{13}) electrodes and opposite (C_{17}) electrodes; it has been studied that adjacent pairs gives the minimum values for C_n while the opposite electrodes shows the maximum. It can also be said after analysis of the normalised capacitances that the opposite electrode pairs gives the best possible result for all the distribution models presented.

x. Based on the knowledge of gas volume fraction, it has been observed that the measured capacitances obtained from the distribution models for different electrode combinations (as defined earlier) for adjacent electrode pair; it decreases, for 1-adjacent electrodes apart and opposite electrodes; it increases linearly on increase in gas volume fraction.

xi. The average void fraction of the ECT sensor also calculated using these normalised capacitance measurements as well as by using the normalised pixel values obtained from ECT images. The measurements obtained from these were in good agreement with our reference measurement of void fraction obtained using delta-P. Both the methods follow the similar trend with respect to the increase in air flow rates.

xii. The estimation of void fraction using the differential pressure measurements was found to be increasing with increase in superficial gas velocity. The gas void fraction was initially a linear function of the superficial gas velocity, typical of the homogenous bubble flow regime. The data obtained from the differential pressure transducers were based on average measurements.

xiii. This study has estimated the volume void fraction using the photographic technique in a vertical upward column. It was also analysed and validated from this technique that void fraction is a linear function of superficial gas velocity. On lower gas flow rate it shows a rapid increase in void fraction while, on higher gas flow rate the change in void fraction becomes steadily.

xiv. When the drift-flux model was applied, it was found that the experimental results obtained for this study were in good agreement with the results obtained by this model at different values of C_0 and V_{gj}.

xv. On applying the polynomial regression it was found that the measured (from experimental) and calculated (from drift-flux model) values of void fraction having the average percentage deviation in the range of ± 20%.

xvi. The absolute difference in measurements between ECT and ΔP were in the range of +4% to +12%. However, both the techniques follow the same increasing trend with respect to the increase in superficial gas velocity.

6.2 Recommendations for Future Work

Some of recommendations for the purpose of improving the future research on void fraction calculation by using ECT and delta-P is listed.

i. The simulation for two-phase flow measurement was not included in the research scope. However, it can be studied by using some finite element (FEM) software package.

ii. The variation in temperature information may be used to compensate the permittivity readings.

iii. This study of void fraction was limited to the lower range of flow rates for air and deionised water. For future research, it can be upgraded to higher range of fluid flows in order to analyze the measurements on a broader scale.

iv. For the future work it is also proposed that, a co-current ejector bubble column pilot plant (i.e. available in UTP Chemical Engineering Department) can be considered for the estimation of void fraction by implementing the ECT technique. However, it is necessary to make some design changes in the existing pilot plant. In order to make this system compatible for the new experiments, a segment of co-current column "K1" (as shown in Appendix '*F*') which is for vertical up-flow needs to be replaced by a "Capacitance Sensor" having electrodes on its periphery to measure the void fraction in conjunction with ECT system. The proposed layout for this new setup is shown in Appendix '*G*'.