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Advanced Tomographic Flow Diagnostics for Opaque Multiphase Fluids

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Advanced Tomographic Flow Diagnostics for Opaque Multiphase Fluids

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Abstract

This report documents the work performed for the "Advanced Tomographic Flow Diagnostics for Opaque Multiphase Fluids" LDRD (Laboratory-Directed Research and Development) project and is presented as the fulfillment of the LDRD reporting requirement. Dispersed multiphase flows, particularly gas-liquid flows, are industrially important to the chemical and applied-energy industries, where bubble-column reactors are employed for chemical synthesis and waste treatment. Due to the large range of length scales (10^{-6}-10^{1} m) inherent in real systems, direct numerical simulation is not possible at present, so computational simulations are forced to use models of subgrid-scale processes, the accuracy of which strongly impacts simulation fidelity. The development and validation of such subgrid-scale models requires data sets at representative conditions. The ideal measurement techniques would provide spatially and temporally resolved full-field measurements of the distributions of all phases, their velocity fields, and additional associated quantities such as pressure and temperature. No technique or set of techniques is known that satisfies this requirement. In this study, efforts are focused on characterizing the spatial distribution of the phases in two-phase gas-liquid flow and in three-phase gas-liquid-solid flow. Due to its industrial importance, the bubble-column geometry is selected for diagnostics development and assessment. Two bubble-column testbeds are utilized: one at laboratory scale and one close to industrial scale. Several techniques for measuring the phase distributions at conditions of industrial interest are examined: level-rise measurements, differential-pressure measurements, bulk electrical impedance measurements, electrical bubble probes, x-ray tomography, gamma-densitometry tomography, and electrical impedance tomography. The first four techniques provide either spatially averaged or local information and are discussed in the context of validation. Although already well developed, the fifth technique is not suitable for large-scale flow experiments but is useful for validation efforts. The last two techniques are investigated and discussed in detail, and representative phase-distribution results are presented for gas-liquid and gas-liquid-solid flows in the two testbeds at conditions of interest.

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Table of Contents

Table of Contents 5
List of Figures 7
List of Tables 9
Nomenclature 11
1. Introduction 14
1.1. Overview 14
1.2. Motivation 14
1.3. Slurry Bubble-Column Reactors (SBCRs) 18
1.4. Scope of Existing and Proposed Diagnostics 21
2. Diagnostic Techniques 23
2.1. Techniques Yielding Spatially-Averaged or Local Information 23
2.1.1. Level-Rise (LR) Technique 23
2.1.2. Differential-Pressure (DP) Technique 24
2.1.3. Bulk Electrical Impedance (BEI) Technique 26
2.1.4. Electrical Bubble Probe (EBP) 27
2.2. X-Ray Tomography (XRT) and Real-Time Radiography (RTR) Techniques 30
2.2.1. XRT System 30
2.2.2. RTR System 31
2.3. Gamma-Densitometry Tomography (GDT) Technique 31
2.3.1. GDT System 32
2.3.2. GDT Reconstruction Algorithm 39
2.4. Electrical-Impedance Tomography (EIT) Technique 41
2.4.1. EIT System 42
2.4.2. EIT Reconstruction Algorithm: Overview 45
2.4.3. EIT Reconstruction Algorithm: Theory 48
2.4.4. EIT Reconstruction Algorithm: FEMEIT Implementation 52
2.4.5. EIT Reconstruction Algorithm: FEMEIT Validation 55
2.4.6. EIT Reconstruction Algorithm: Extensions 59
3. Preliminary Validation Efforts 61
3.1. Wax/Catalyst (WCD) Experiments 61
3.1.1. WCD Description 61
3.1.2. WCD Experimental Results from XRT 62
3.2. Boxed Bubble Column (BBC) Experiment 65
3.2.1. BBC Experimental Setup 66
3.2.2. BBC Experimental Results from RTR 67
3.3. Insulating Cylindrical Inclusion (ICI) Experiments 69
3.3.1. ICI Experimental Setup 69
3.3.2. ICI Experimental Results from EIT 70
4. Experimental Testbeds and Results 72
4.1. Transparent Bubble Column (TBC) Experiment 72
4.1.1. TBC Experimental Setup 73

4.1.2. TBC Experimental Results 75
4.2. Slurry Bubble-Column Reactor (SBCR) Experiment 79
4.2.1. SBCR Experimental Setup 80
4.2.2. SBCR Experimental Results 80
4.3. Two-Phase Experiments Combining GDT and EIT 84
4.3.1. Liquid-Solid Flow (LSF) Experiment 85
4.4. Application of GDT and EIT to TBC 89
5. Conclusions 93
A. FEMEIT Files 94
References 96
Distribution 102

List of Figures

Figure 1. Nondilute turbulent gas-liquid flow. 15
Figure 2. Terminal velocity of an isolated air bubble in water (Jamialahmadi et al., 1994). 16
Figure 3. Los Alamos CFDLIB calculation of bubble-column flow (Kumar et al., 1995b). 17
Figure 4. Slurry bubble-column reactor (SBCR) schematic diagram. 19
Figure 5. SBCR photograph and process diagram, courtesy of Air Products and Chemicals. 20
Figure 6. Schematic diagram of level-rise (LR) technique. 24
Figure 7. Schematic diagram of differential-pressure (DP) technique. 25
Figure 8. Bulk electrical impedance (BEI) probe ring with two rectangular electrodes. 26
Figure 9. Electrical bubble probe (EBP) schematic, bubble interceptions, and rms correlation. . 28
Figure 10. Gas volume fraction radial distributions from EBP. 29
Figure 11. X-ray tomography (XRT) experimental setup. 30
Figure 12. Gamma-densitometry tomography (GDT) system. 32
Figure 13. A detector erroneously observes some of the scattered gamma photons. 33
Figure 14. Schematic diagram of traverse for source and detector. 34
Figure 15. Gamma spectrum from the MCA with various features identified. 35
Figure 16. Gamma spectra from the MCA with various thicknesses of water. 37
Figure 17. Logarithmic gamma spectra (points) and peak-fitting algorithm (curves). 38
Figure 18. Schematic diagram of Abel transform geometry. 39
Figure 19. Schematic diagram of electrical-impedance tomography (EIT). 41
Figure 20. Block diagram of EIT hardware. 42
Figure 21. EIT strip and point electrodes and probe-ring installations. 44
Figure 22. Schematic diagram of EIT. 45
Figure 23. Linearity allows all EIT solutions to be built up from fewer solutions. 47
Figure 24. EIT mesh refinement studies. Good convergence is observed. 56
Figure 25. 2DynaEIT (Duraiswami et al., 1995) and FEMEIT ICI reconstructions. 58
Figure 26. EIT determination of radius of an ICI using point electrodes and EITA3D. 60
Figure 27. Wax/catalyst disk (WCD) samples with hole patterns. 61
Figure 28. XRT resolution study for “large-signature” WCD. 63
Figure 29. XRT resolution study for “quadrant calibration” WCD. 64
Figure 30. Boxed bubble-column experiment. 66
Figure 31. Schematic diagram of RTR applied to BBC experiment. 67
Figure 32. RTR results for BBC experiment. 68
Figure 33. Schematic diagram of EIT with an insulating cylindrical inclusion (ICI). 69
Figure 34. EIT reconstructions of insulating cylinders using strip electrodes. 71
Figure 35. The transparent bubble-column (TBC) experiment. 72
Figure 36. Sparger (final design) in TBC. 73
Figure 37. Temperature-dependent electrical conductivity can give spurious results. 74
Figure 38. Count-rate results from GDT in TBC. 75
Figure 39. Gas-liquid and gas-liquid-solid results from GDT in TBC. 77
Figure 40. Phase volume fraction results from GDT in TBC. 78
Figure 41. The slurry bubble-column reactor (SBCR) experiment. 79

Figure 42. Gas volume fraction results from DP for gas-liquid flow in SBCR. 81
Figure 43. Gas volume fraction results from GDT for gas-liquid flow in SBCR. 82
Figure 44. Gas volume fraction vertical variation from DP and GDT in SBCR. 84
Figure 45. The liquid-solid flow (LSF) experiment. 86
Figure 46. Solid volume fraction results from GDT and EIT in LSF. 88
Figure 47. GDT and EIT installed in TBC for measuring gas-liquid flow. 90
Figure 48. GDT and EIT results at same conditions in TBC. 91

List of Tables

Table 1.	Nondimensionalization employed in EIT theoretical development.	47
Table 2.	EITA3D reconstructions of ICI diameters.	70
Table 3.	Average gas volume fractions in TBC.	76
Table 4.	Average gas volume fraction values from GDT and DP for air-water in SBCR.	83
Table 5.	Conditions and results for LSF experiment.	87