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PARTICLE COATING USING FOAMS AND BUBBLES

A thesis presented in partial fulfilment of the requirements for the degree of

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Shakti Singh

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ABSTRACT

This thesis investigates powder coating using foams or bubbles. The work initially started on foams. Wettability studies first showed that foams can be used to coat powders. Research then focussed on the fundamental unit of foams, the bubble. An experimental apparatus was designed and built to perform particle-bubble impact studies in air. Bubble solutions comprised of water, hydroxypropyl methylcellulose (HPMC) and sodium dodecyl sulphate (SDS). Four distinct physical behaviours occur when a particle impacts a bubble: (i) particle capture, (ii) particle slide-off, (iii) bubble burst and (iv) bubble self-healing.

The rate processes that occur during particle-bubble impact are; (i), surface area creation by bubble film stretching; (ii), delivery of surface active molecules to the newly created surface; and (iii), stress dissipation as the film is stretched. The ability of the solutions to do (ii) and (iii) are highly complex relying on the thermodynamic equilibrium of the solutions and the local perturbations in the near surface region. Therefore, establishing quantitative boundaries of behaviour is a difficult exercise. It is proposed that, for solutions above the *cac* or *cmc*, (*critical aggregate concentration*, *critical micelle concentration*) where self-healing occurs, the rate of (ii) > rate of (i) and the rate of (iii) > rate of (i). For solutions below the *cac*, where bursting occurs, the opposite is true, the rate of (ii) < rate of (i) and the rate of (iii) < rate of (i). Intermediate behaviours such as slide-off of capture are within the range of self-healing behaviours, but where the energy of the particle is insufficient to penetrate the bubble.

These behaviours are explained by complexation theory. For SDS concentration \geq *cac* and *cmc*, small aggregates of SDS and HPMC locally supply surfactant to the surface of the stretching bubble film. This maintains low surface tension stress and self-healing

results. For SDS concentrations $< cac$, self-healing occurs because the complexation is a HPMC-SDS sea containing SDS islands. The HPMC-SDS sea structure is sufficiently interlinked to simply stretch with the film, while the SDS islands de-aggregate quickly in the near surface region to supply the newly created surface with surfactant. Here the supply rate is faster than the stretching and so the new surface area is populated with SDS molecules. In contrast bursting occurs when the complexation is HPMC-SDS islands in a SDS sea. Here, the rapid film extension is so fast that the islands of HPMC-SDS become isolated and the film loses structural homogeneity. Furthermore, the rate of new surface creation is too fast for diffusion of SDS molecules from the bulk 'sea' to the newly created surface. This results in both an inhomogeneous structure and local increases in surface tension, causing both stress concentration in the film and the Marangoni effect.

Extensional viscosity measurements, conducted in collaboration with Monash University, Australia, produced three behaviours as solutions were thinned: bead-on-string, blob and long-lived filaments. Solutions which produced long lived filaments here correspond to those that self-healed during particle impact (when the impact velocity was sufficient). It is proposed that this long-lived filament behaviour is due to the SDS concentration being $> cmc$, where the SDS micelles act like 'ball-bearings' between the extending HPMC chains.

Coatings were characterised by SEM and gravimetric measurement. Cross-sectional imaging of the soft particle that penetrated self-healing bubbles were found to have a continuous coating layer around the particle. Surface topography of bubble coated particles were compared with classical droplet coated single particles from the literature. Bubble coated particles were found to be smoother than the droplet coated particle.

The knowledge gained here was used to suggest how an industrial-scale particle coater using bubbles may be designed.

I wish you could see it Babuji (Dad)!

With the blessings of my father, Late Mr J.P. Singh and mother, Mrs Durgavati Singh

I dedicate this work to my wife, Renu and son, Advait

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TABLE OF CONTENTS

ABSTRACT	i
ACKNOWLEDGEMENTS	vii
CHAPTER 1 THESIS OVERVIEW	1
1.1 CONTEXT	1
1.2 PROBLEM DEFINITION	1
1.3 PROPOSED SOLUTION	2
1.4 THESIS OBJECTIVE	4
1.4.1 Overall thesis objective	4
1.4.2 Specific thesis objectives.....	4
1.5 THESIS OUTLINE	6
1.6 POTENTIAL OUTCOMES.....	7
CHAPTER 2 REVIEW OF LITERATURE	9
2.1 INTRODUCTION.....	9
2.2 FILM COATING ON POWDERS.....	9
2.3 FOAM.....	13
2.3.1 Foam production	16
2.4 PHYSICAL PROPERTIES OF THE FOAM SYSTEMS.....	16
2.4.1 Surface tension.....	16
2.4.2 Surface rheology	18
2.5 FOAM DESTABILISATION MECHANISMS	19
2.5.1 Defoaming and antifoaming	22
2.5.2 Foam film drainage	25
2.6 POLYMER-SURFACTANT COMPLEXATION.....	27
2.6.1 Polymer-surfactant complexation in a solution	27

2.6.2 Polymer-surfactant interactions at an interface.....	30
2.7 SPREADING BEHAVIOUR OF A SURFACTANT DROP ON A SURFACE .	32
2.8 WETTABILITY ASSESSMENT OF POWDERS	34
2.9 PRIOR ART AND THE KNOWLEDGE GAP	37
CHAPTER 3 HYPOTHESIS TESTING AND CHARACTERISATION OF FOAM COATED PARTICLES	45
3.1 INTRODUCTION	45
3.2 EXPERIMENTAL OPTIMISATION	45
3.2.1 Selection of model particle system	45
3.2.2 Optimisation of foaming and coating procedure	48
3.2.3 Materials	49
3.2.4 Methods	50
3.2.4.1 Particle silanisation	50
3.2.4.2 Particle coating using foam	50
3.2.5 Coating structure characterisation.....	51
3.3 POWDER CHARACTERISATION	51
3.3.1 Wettability assessment	51
3.3.1.1 Visual wettability assessment.....	52
3.3.1.2 Modified sessile drop technique	52
3.3.1.3 Gel trapping technique	53
3.3.1.4 Micro-level wettability studies by ESEM	55
3.4 RESULTS AND DISCUSSION.....	56
3.4.1 Wettability studies.....	56
3.4.1.1 Modified sessile drop technique	56
3.4.1.2 Visual assessment of particle behaviour on water	58
3.4.1.3 Single particle wettability using the gel trapping technique	59
3.4.1.4 Micro level wettability studies using ESEM	61

3.4.2 Coating structure using confocal laser scanning microscope.....	67
3.5 CONCLUSIONS	68
CHAPTER 4 DEVELOPMENT OF AN EXPERIMENTAL APPARATUS	71
4.1 INTRODUCTION.....	71
4.2 EXPERIMENTAL APPARATUS	72
4.2.1 Single bubble generation	73
4.2.2 Particle-bubble contacting	77
4.2.3 Mass transfer per particle-bubble impact	81
4.2.4 Video capture.....	82
4.3 PRELIMINARY STUDIES: BUBBLE GENERATION	85
4.3.1 Experimental rig.....	85
4.3.2 Experimental protocol	87
4.3.3 Results and discussion.....	89
4.3.4 Conclusions-Bubble generation	98
4.4 PRELIMINARY STUDIES: PARTICLE-BUBBLE IMPACT.....	100
4.4.1 Stationary particle suspended over a bubble	101
4.4.2 Bubble gun.....	102
4.4.3 Falling particle dropped by a particle tweezer.....	103
4.5 CONCLUSIONS	108
CHAPTER 5 VARIABLE SELECTION AND PHYSICAL CHARACTERISATION OF BUBBLE SOLUTIONS AND PARTICLES	111
5.1 INTRODUCTION.....	111
5.2 KEY VARIABLES AND LEVEL SELECTION	112
5.2.1 Bubble solution	113
5.2.2 Particle type	113
5.2.3 Particle impact speed.....	114
5.3 EXPERIMENTAL PROTOCOL	115

5.3.1 Solution preparation	115
5.3.2 Cleaning and surface modification of glass particles	115
5.3.3 Shear viscosity measurement	116
5.3.4 Contact angle measurements	116
5.3.5 Surface tension measurements	117
5.3.6 Bubble film thickness measurement using FT-IR spectroscopy.....	117
5.4 RESULTS AND DISCUSSION.....	118
5.4.1 Shear viscosity measurement.....	118
5.4.1.1 Influence of concentrations and shear rates on shear viscosity	118
5.4.1.2 Influence of SDS concentration on the shear viscosity of HPMC solutions	119
5.4.2 Surface tension measurements.....	122
5.4.2.1 Influence of HPMC concentration in SDS solution	122
5.4.2.2 Influence of HPMC concentration in an aqueous solution	123
5.4.2.3 Influence of SDS concentration in HPMC solution	124
5.4.3 Wettability (contact angle) of aqueous HPMC-SDS solutions on a glass slide	127
5.4.3.1 Influence of HPMC concentration.....	127
5.4.3.2 Influence of SDS concentration.....	128
5.4.4 Bubble film thickness measurement using FT-IR spectroscopy.....	131
5.5 CONCLUSIONS	133
CHAPTER 6 PARTICLE-BUBBLE IMPACT BEHAVIOUR	135
6.1 INTRODUCTION.....	135
6.2 PREDICTING PARTICLE-BUBBLE IMPACT BEHAVIOUR	135
6.3 EXPERIMENTAL.....	141
6.4 RESULTS AND DISCUSSION.....	142
6.4.1 Qualitative observation.....	142

6.4.1.1 Influence of particle to bubble diameter ratio and particle impact speed	152
6.4.1.2 Influence of particle shape, surface properties and particle impact speed	152
6.4.1.3 Influence of impact angle and impact velocity	155
6.4.2 Qualitative explanation of particle-bubble impact outcomes	160
6.4.2.1 Marangoni effect	160
6.4.2.2 HPMC-SDS complexation	162
6.5 Physical description of particle-bubble impact dynamics	173
6.5.1.1 Relative influence of bubble solution viscosity and surface tension	178
6.5.1.2 Influence of particle surface properties	179
6.5.1.3 Influence of bubble solution surface tension	182
6.6 REGIME MAP OF PARTICLE-BUBBLE IMPACT BEHAVIOUR	182
6.7 CONCLUSIONS	195
CHAPTER 7 EXTENSIONAL FLOWS AND PARTICLE-BUBBLE IMPACT BEHAVIOUR	
7.1 INTRODUCTION	197
7.2 ACOUSTICALLY DRIVEN MICROFLUIDIC RHEOMETER	199
7.2.1 Materials	201
7.2.2 Method	201
7.3 RESULTS AND DISCUSSION	202
7.3.1 Film thinning behaviour vs. particle-bubble impact behaviour	202
7.3.2 Proposed molecular association in the film vs. impact behaviour	208
7.3.3 Extensional viscosity measurements of bubble solutions	211
7.4 CONCLUSIONS	216
CHAPTER 8 BUBBLE COATED SINGLE PARTICLE CHARACTERISATION ...	
8.1 INTRODUCTION	219

8.2 EXPERIMENTAL.....	219
8.2.1 Materials	219
8.2.2 Methods	220
8.2.2.1 Particle-bubble contact.....	220
8.2.2.2 Theoretical coating thickness calculations.....	220
8.2.2.3 Surface structure studies using SEM	220
8.3 RESULTS AND DISCUSSION.....	221
8.3.1 Weight gain and coating thickness.....	221
8.3.2 Scanning electron microscopic studies of bubble coated particles	224
8.3.2.1 Surface topography of bubble film coated particles	224
8.4 CONCLUSIONS	228
CHAPTER 9 RECOMMENDATIONS FOR INDUSTRIAL-SCALE COATING USING BUBBLES	231
9.1 INTRODUCTION	231
9.2 CONCEPTUAL INDUSTRIAL-SCALE COATER.....	231
9.2.1 Operating principles	232
9.2.2 Bubble generator	232
9.2.3 Particle disperser	233
9.2.4 Coated particle fluidisation for drying	234
9.3 MICRO-LEVEL PROCESS IDENTIFICATION.....	236
9.4 CONCLUSIONS AND RECOMMENDATIONS.....	238
CHAPTER 10 CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK.....	241
10.1 GENERAL CONCLUSIONS	241
10.2 SUGGESTED FUTURE WORK	243
BIBLIOGRAPHY	245
APPENDICES	267

10.3 SURFACE CREATION RATES WHEN A PARTICLE IMPACTS A BUBBLE
..... 267

10.4 MASS TRANSFER FROM BUBBLE TO PARTICLE 268

LIST OF FIGURES

Figure 1-1: Schematic of film coating of a particle.	3
Figure 2-1: Cross-section of Wurster coater and phenomena occurring during particle coating Adapted from Werner et al. (2007).	11
Figure 2-2: Possible phenomena taking place during fluidised bed coating. Adapted from (Nienow, 1995).	12
Figure 2-3: Foam nomenclature (Denkov, 2004).	14
Figure 2-4: Microstructure of a foam film.	15
Figure 2-5: Schematic showing change of surface tension with time of a foaming solution with different types of surfactants; type III may be ideal for high foamability and stability.	18
Figure 2-6: Mechanism of foam destabilisation, adapted from Oungbho et al. (1997).	21
Figure 2-7: Coarsening with time, adapted from Saint-Jalmes (2006).	22
Figure 2-8: Antifoaming mechanism, adapted from Denkov et al. (2004).	23
Figure 2-9: Schematic presentation of bridging-dewetting mechanism for smooth spherical particle ($\theta > 90^\circ$) and for rough non-spherical particle. Adapted from Denkov et al. (2004).	24
Figure 2-10: Antifoaming by hydrophobic particle and simultaneous deactivation of antifoaming activity. Adapted from Kulkarni et al. (1977b).	25
Figure 2-11: (a) Monolayer, (b) Newton black film, (c) Common black film, (d) Thick foam film.	27
Figure 2-12: Polymer-surfactant complex formations at different polymer/surfactant concentration combinations. Solid black lines represent HPMC chains, blue and yellow spheres represent to SDS micelle and counter ions, adapted from (Nilsson, 1995; Silva et al., 2011). The larger blue sphere indicates major hydrophobic association zones.	29
Figure 2-13: Schematic of the graph of the surface tension with log concentration of the surfactant in the polymer aqueous solution; molecular level interaction is also shown in the inset (adapted and modified from (Jones, 1967)).	30
Figure 2-14: Polymer-surfactant complexation at the air-water interface; long chain molecules are polymers, short chain with circular head are surfactants Adapted and modified from (Cooke, Dong, et al., 1998; Dong, Sun, Liu, Cao, & Jiang, 2009).	32

Figure 2-15: Schematic of the dynamics of surfactant molecules in an aqueous drop over a hydrophobic surface. Adapted from (Ruckenstein, 2012).	33
Figure 2-16: Forces involved on a droplet placed on a solid surface.	34
Figure 2-17: Mechanism of foam generation on interaction with powder. Adapted and modified from (Prud'homme, 1996).	39
Figure 3-1 Antifoaming silica after foam processing.	46
Figure 3-2: (a) Image of the planetary mixer and (b) Schematic of the sparging column used for foaming surfactant/protein solution.	48
Figure 3-3: Schematic of wettability assessment, (a) Sessile drop method, (b) Gel trapping technique, and (c) ESEM technique.	52
Figure 3-4: Relative protrusion of particle in PDMS elastomer matrix Adapted and modified from (Cayre and Paunov, 2004); (a) Hydrophilic particle embedded in PDMS base, (b) Hydrophobic particle embedded in PDMS base.	55
Figure 3-5: (a) Original image, (b) Processed image for edge detection and contact angle measurement.	56
Figure 3-6: Particle wicking phenomenon; the arrows indicate the upper limit of the glass powder layer.	57
Figure 3-7: (a) Sessile drop on, (a) Silanised particle bed, (b) Surfactant foam coated silanised particle bed.	58
Figure 3-8: (a) Low and (b) High magnification SEM images of silanised glass particles trapped in polydimethylsiloxane.	59
Figure 3-9: (a) Low and (b) High magnification SEM images of surfactant foam coated silanised glass particles trapped in polydimethylsiloxane.	60
Figure 3-10: ESEM images of surfactant foam coated silanised glass particles at (a) high and (b) low chamber pressure.	62
Figure 3-11: ESEM images, (a) and (b) of silanised glass particles for contact angle measurement at different locations.	62
Figure 3-12: ESEM images, (a), (b), (c) and (d) of surfactant foam coated silanised particles captured at different locations for contact angle measurement.	63
Figure 3-13: ESEM images, (a), (b), (c) and (d), of high concentration surfactant foam coated silanised glass particles captured at different locations for contact angle measurement.	64
Figure 3-14: ESEM images, (a) with little condensation and (b) with moderate condensation of protein foam coated silanised glass particles.	65

Figure 3-15: <i>Rhodamine-B stained sodium caseinate foam coated glass ballotini: (a) 3-D view showing upper surface, (b) a single z-slice of surfactant coated glass particle at the equator.</i>	67
Figure 4-1: <i>Conceptual key-processes of particle coating using foams or bubbles.</i>	71
Figure 4-2: <i>(a) Co-flowing capillary nozzle, (b) T-junction nozzle.</i>	74
Figure 4-3: <i>Hamilton needle connected with T-junction.</i>	75
Figure 4-4: <i>Micro-syringe pump to supply bubble liquid and air at the T-junction.</i>	76
Figure 4-5: <i>Bubble nozzle fixed on a Vernier calliper in a polycarbonate chamber.</i> ...	77
Figure 4-6: <i>Particle tweezer connected to a suction pump through PVC tube on a z-moving stage.</i>	79
Figure 4-7: <i>Particle-bubble impact chamber and the particle tweezer's base table, fixed on the anti-vibration plate.</i>	80
Figure 4-8: <i>Impact chamber with particle tweezer and bubble nozzle alignment strings.</i>	81
Figure 4-9: <i>High speed camera on an x, y and z moving stage with a macro-lens.</i>	83
Figure 4-10: <i>Schematic diagram of experimental apparatus for single particle-bubble impact study. (A); camera with macro-lens, (B); X,Y,Z moving stage, (C); computer, (D) and (E); syringe pumps connected to T-junction, (F); vacuum pump with a 2-way stopcock (M), (G); particle handler fixed with z-moving stage stationed on the table (N), (H); particle attached with particle handler, (I); rectangular polycarbonate chamber (J) bubble stationed on the nozzle, (K); bubble nozzle fitted with movable scale, (L); LED to illuminate bubble.</i>	84
Figure 4-11: <i>(a) Hamilton needles, (b) T-junctions.</i>	86
Figure 4-12: <i>Experimental set-up to explore mechanism of bubble formation in air.</i> ..	87
Figure 4-13: <i>Liquid slug and air pocket formation at a T-junction; (a), initial formation and wetting; (b), sequential liquid slugs and air pockets; and (c), liquid slug movement into the nozzle. Eight to ten air and liquid slugs were measured and averaged at each experimental condition.</i>	90
Figure 4-14: <i>Observation of bubble formation at a T-junction; (a) – (e) progression of a liquid slug followed by an air pocket to expand into a bubble with some drainage (see (d)) down the outside of the nozzle.</i>	91
Figure 4-15: <i>Bubble generation behaviour for trial with HPMC-3% (w/v) in a 2.2 mm T-junction topped by a needle with internal diameter 1.6 mm, (a) bubble chaining phenomenon, (b) bubble slide-off phenomenon, and (c) bubble burst phenomenon.</i>	92

Figure 4-16: <i>Liquid slug length (H_L) (mm) as a function of air/solution ratio for trials with HPMC-3% (w/v) in a 2.2 mm and 1.1mm T-junction at low flow rates (0.2 mL/min liquid flow rate).</i>	94
Figure 4-17: <i>Liquid slug length (H_L) (mm) as a function of air to liquid ratio for trials with HPMC-3% (w/v) in a 2.2 mm and 1.1 mm T-junction at high flow rates (0.04 mL/ml liquid flow rate).</i>	94
Figure 4-18: <i>Air slug length (H_A) (mm) as a function of air to liquid ratio for trials with HPMC-3% (w/v) in a 2.2mm and 1.1 mm T-junction at low flow rates (0.2 mL/min liquid flow rate).</i>	95
Figure 4-19: <i>Air slug length (H_A) (mm) as a function of air to liquid ratio for trials with HPMC-3% (w/v) in a 2.2 mm and 1.1 mm T-junction at high flow rates 0.04 mL/min liquid flow rate).</i>	95
Figure 4-20: <i>Terminal bubble diameter (d_B) (mm) observed before slide-off or burst as a function of air/solution ratio for trials with HPMC-3% (w/v) in a 2.2 mm and 1.1 mm T-junction at low flow rate ratios.</i>	97
Figure 4-21: <i>Terminal bubble diameter (d_B) (mm) observed before slide-off or burst as a function of air/solution ratio for trials with HPMC-3% (w/v) in a 2.2 mm and 1.1mm T-junction at high flow rate ratios.</i>	97
Figure 4-22: <i>Terminal bubble diameter observed before slide-off or bursting as a function of needle internal diameter for trials with HPMC-3% (w/v) in a 2.2 mm T-junction.</i>	98
Figure 4-23: <i>Selected image sequence from left to right of (a) a dry glass particle of 2 mm diameter (b) a bubble film coated wet glass particle, with a (HPMC-5% (w/v) aqueous bubble) ($\mu = 0.014$ Pa.s, $\sigma = 45.59$ mN/m).</i>	102
Figure 4-24: <i>Selected image sequence of impact between a moving SDS-water; $\mu = 0.001$ Pa.s, $\sigma = 34.2$ mN/m, bubble generated by a bubble gun and a 1mm glass particle hung by a copper wire.</i>	102
Figure 4-25: <i>Selected image sequence of particle-bubble interaction between (a) a 0.25% (w/v) SDS-water bubble of 7.0 ± 0.5 mm diameter and a spherical glass particle of 1 mm, (b) a 0.26% (w/v) HPMC-water bubble of 7.0 ± 0.5 mm diameter and a spherical glass particle of 1 mm. Time difference between two images is 0.5 ms.</i>	104
Figure 4-26: <i>Selected image sequence of particle-bubble interaction behaviours with (a) a SDS-water bubble (b) HPMC-water bubble, particle position was fixed and bubble</i>	

<i>inflated and (c) SDS-water bubble was inflated beneath a hydrophilic particle hung by the particle tweezer.</i>	106
Figure 4-27: <i>Selected images showing bubble bursting pattern when a glass particle of 1 mm diameter impacts with a bubble of (a) SDS-water, 0.25% (w/v), (b) HPMC-water, 0.015% (w/v), (c) HPMC-water, 0.065% (w/v), (d) HPMC-water, 0.520% (w/v). The number above each image is time after first impact between a particle and a bubble.</i>	107
Figure 5-1: <i>Schematic of bubble scanning sung FT-IR spectroscopy for bubble film thickness measurements.</i>	117
Figure 5-2: <i>Influence of polymer concentration and shear rate on viscosity of HPMC aqueous solution (n=1).</i>	119
Figure 5-3: <i>Comparison of the shear viscosity of 0.065 to 1.0% (w/v) HPMC aqueous solution each at five levels of SDS concentration from 0-9 mM L⁻¹ at 15 s⁻¹ shear rate (n=1).</i>	120
Figure 5-4: <i>Surface tension of aqueous solution of SDS and HPMC-SDS (n=3, S.E).</i>	123
Figure 5-5: <i>Influence of HPMC concentration on the equilibrium surface tension of aqueous solution, (n=3, S.E.).</i>	124
Figure 5-6: <i>Top: Surface tension graph of HPMC-SDS aqueous solution at 0.065 - 1.0 % (w/v) concentration of HPMC with six levels of SDS surfactant: 0 mM L⁻¹, 0.56 mM L⁻¹, 1.12 mM L⁻¹, 2.25 mM L⁻¹, 4.5 mM L⁻¹ and 9 mM L⁻¹, at each HPMC concentrations (n=3, S.E.). Bottom: Schematic of surface tension isotherm showing T1 (cac of surfactant) and T2 (cmc of surfactant) in polymer-surfactant (neutral-anionic) solutions.</i>	126
Figure 5-7: <i>Influence of HPMC concentrations on the contact angle with hydrophilic and hydrophobic glass slides, (n=3, S.E.).</i>	128
Figure 5-8: <i>Contact angles of hydrophilic glass slide with aqueous HPMC and HPMC-SDS solutions (n = 3, S.E.).</i>	129
Figure 5-9: <i>Contact angles of hydrophobic glass slide with aqueous HPMC and HPMC-SDS solutions (n = 3, S.E.).</i>	130
Figure 5-10: <i>Film thicknesses of aqueous bubbles of 0.065% (w/v), 0.26% (w/v), 0.52% (w/v) and 1.0% (w/v) HPMC with three levels; 0 mM L⁻¹, 2.25 mM L⁻¹, and 9 mM L⁻¹ of SDS using FT-IR spectroscopy, (n=5, S.E.).</i>	132
Figure 6-1: <i>(a)-(f) Envisaged particle-bubble impact behaviour.</i>	140
Figure 6-2: <i>Impact behaviour diagram showing how the combinations of bubble formulation, particle properties and impact velocity determine the impact behaviour. Qualifications of surface tension are ~40 mN/m when SDS was combined with HPMC,</i>	

~ 56 mN/m when only HPMC was used, and in-between when SDS and HPMC were used together..... 145

Figure 6-3 Selected image sequence (top to bottom) illustrating particle-bubble impact behaviour, (a) HPMC-0.065% (w/v)-0 mM L⁻¹ SDS (b) HPMC-0.26% (w/v)-0 mM L⁻¹ SDS (c) HPMC-1.0% (w/v)-0 mM L⁻¹ SDS (d) HPMC-0.065% (w/v)-2.25 mM L⁻¹ SDS (e) HPMC-0.26% (w/v)-2.25 mM L⁻¹ SDS (f) HPMC-1.0% (w/v)-2.25 mM L⁻¹ SDS (g) HPMC-0.065% (w/v)-9 mM L⁻¹ SDS (h) HPMC-0.260% (w/v)-9 mM L⁻¹ SDS (i) HPMC-1.0% (w/v)-9 mM L⁻¹ SDS. All bubbles ($\varnothing 6.5 \pm 1.0$ mm) are impacted by a 1 mm glass particle at 9.0 m s⁻¹. The number in the time column is the time after first impact in ms. 147

Figure 6-4: Self-healing phenomenon with varying particle types; (a) smooth spherical hydrophilic glass particle of 1 mm diameter and impact velocity 1.2 m/s, (b) smooth spherical hydrophobic glass particle of 1 mm diameter and impact velocity 1.2 m/s, (c) smooth spherical hydrophobic glass particle of 2 mm diameter and impact velocity 1.2 m/s, (d) rough cylindrical hydrophilic glass particle of 1.5 mm diameter and impact velocity 1.2 m/s, (e) rough cylindrical hydrophilic glass particle of 1.5 mm diameter and impact velocity 2.1 m/s, (f) smooth spherical hydrophilic glass particle of 3 mm diameter and impact velocity 2.1 m/s, (g) smooth spherical polyethylene particle of 0.8 mm diameter and impact velocity 2.1 m/s. The bubble formulation was HPMC-0.260% (w/v)-9 mM L⁻¹ SDS, bubble of 6.5 ± 1.0 mm for all particle and impact velocities. The number above each image is the time after first impact in ms. 154

Figure 6-5: Schematic showing impact angle between a particle and a bubble. 155

Figure 6-6: Particle-bubble impact behaviour at higher impact angle; (a) 1 mm hydrophilic or hydrophobic particle impacted with an impact velocity of 0.9 m/s at a central angle more than 15° with a HPMC-0.26% (w/v) bubble, (b) 1 mm hydrophilic or hydrophobic particle impacted with an impact velocity of 0.9 m/s at a central angle more than 15° with a HPMC-1.0% (w/v)-9 mM L⁻¹ SDS bubble, (c) 1 mm hydrophilic or hydrophobic particle impacted with an impact velocity of 3.3 m/s at a central angle more than 15° with a HPMC-1.0% (w/v)-9 mM L⁻¹ SDS bubble. The number above each image is the time after first impact in ms. The small imperfection seen in this image is due to a small bubble attached to the inner wall of the larger bubble..... 157

Figure 6-7: Surface tension curves of HPMC-SDS concentrations combinations showing cac and cmc of SDS and corresponding impact behaviour from a bubble obtained from respective solutions. The cac of SDS for a solution of HPMC-1.0% (w/v) is measured to

<i>be 1.12 mM L⁻¹. For the other HPMC concentrations of 0.52% (w/v), 0.26% (w/v) and 0.065% (w/v), the cac is measured to be 2.25 mM L⁻¹. The cmc of a pure SDS solution is 8.3 mM L⁻¹, but for the binary solutions the cmc is 4.5 mM L⁻¹.</i>	163
Figure 6-8: (A) HPMC, SDS and HPMC-SDS adsorption at interface and in bulk in a bubble film at (a) no SDS in HPMC bubble solution (the sketch shows a HPMC molecule with hydrophilic (blue) and hydrophobic (brown) parts), (b) SDS concentration, $c < cac$, (c) $c=cac$ and (d) $c>cac$, cmc. (B) Corresponding impact outcomes, (a) Bubble burst, Particle capture, (b) Particle slide-off, (c) Bubble self-healing and (d) Bubble self-healing. The schematics of interfacial adsorption of HPMC, SDS and HPMC-SDS are inspired by Dong et al.(2009).	164
Figure 6-9: (a) Schematic of molecular behaviour of (a) a static film (a1) stretching film with replenishment (a2) stretching film which bursts because there is inadequate replenishment and corresponding images (b) of particle-bubble impact behaviour ($c < cac$).	165
Figure 6-10: (a) Schematic of molecular behaviour of (a) a static film (a1) stretching film with replenishment (a2) stretching film which self-heals because there is adequate replenishment and corresponding images (b) of particle-bubble impact behaviour ($c \geq cac$).	166
Figure 6-11: Mechanisms for the two relaxation times for a surfactant solution above critical micelle concentration (cmc). Adapted and reproduced from (Dhara & Shah, 2001b).	170
Figure 6-12: Schematic illustrations of the increase in the number density of SDS aggregates/micelles with HPMC and corresponding explanation for particle-bubble impact behaviour.	172
Figure 6-13: Sequential images (from left to right) of the impact a particle of diameter 1 mm glass onto $\varnothing 7$ mm bubble with formulation of HPMC-1.0% (w/v)-9 mM L ⁻¹ SDS. Impact velocity is 2.1 m/s and time between two images is 0.5 ms. The particle bounced back on colliding with the bubble nozzle at 2.5 ms.	175
Figure 6-14: Measurements of particle and bubble position for a $\varnothing 7$ mm single bubble with formulation of HPMC-1.0% (w/v)-9 mM L ⁻¹ SDS being impacted by a particle of $\varnothing 1$ mm glass at an impact velocity 2.1 m/s.	176
Figure 6-15: Measurements of particle and bubble velocity for a $\varnothing 7$ mm single bubble with formulation of HPMC-1.0% (w/v)-9 mM L ⁻¹ SDS being impacted by a particle of $\varnothing 1$	

<i>mm glass at an impact velocity 2.1 m/s. Velocities are obtained from the smoothed position curves shown in Figure 6-14.</i>	176
Figure 6-16: <i>Experimental deceleration rates for all runs at an impact velocity of 0.9 m/s.</i>	178
Figure 6-17: <i>Deceleration values for all experiments plotted against the surface tension and viscosity.</i>	179
Figure 6-18: <i>The position of 1 mm diameter (a) hydrophilic and (b) hydrophobic glass particles gently place on bubbles of HPMC-0.260% (w/v)-9 mM L⁻¹ SDS after 30 seconds.</i>	180
Figure 6-19: <i>Particle penetration length into the bubble film at 1.5 ms for a HPMC-0.520% (w/v)-0.56 mM L⁻¹ SDS bubble with 1 mm hydrophilic and hydrophobic particles impacting with different velocities ranging between 0.9 m/s to 2.7 m/s (n=5, S.E.).</i> ...	181
Figure 6-20: <i>Particle penetration length of a 1 mm hydrophilic spherical glass particle into bubble films 1.5 ms after impact, obtained from HPMC-0.520% (w/v) with varying concentrations of SDS from 0-9 mM L⁻¹ SDS. The particle impact velocity was 0.9 m/s, (n=5, S.E.).</i>	182
Figure 6-21: <i>(a) Fourier number versus Capillary number, (b) Schmidt versus Capillary number. Both are for an impact velocity of 0.9 m/s of a Ø1 mm diameter particle impacting a ~Ø6.5 mm bubble.</i>	194
Figure 7-1: <i>Acoustic driven microfluidic device for extensional viscosity measurement (Image supplied by Amarin McDonnell).</i>	200
Figure 7-2: <i>Thinning behaviour verses particle-bubble impact behaviour of HPMC solution at different SDS levels.</i>	204
Figure 7-3: <i>Filament thinning behaviour of bubble solution, (a) HPMC-1.0% (w/v)-0 mM L⁻¹ SDS, (b) HPMC-1.0% (w/v)-1.12 mM L⁻¹ SDS, (c) HPMC-1.0% (w/v)-2.25 mM L⁻¹ SDS, (d) HPMC-1.0% (w/v)-9 mM L⁻¹ SDS. The number over each image shows the time from the start of the thinning.</i>	207
Figure 7-4: <i>Schematics of HPMC-SDS molecular interactions in solutions, (a) without SDS, (b) with low to intermediate concentration of SDS tested (0.55-1.12 mM L⁻¹), and (d) with concentration slightly greater than the critical micelle concentration of SDS tested (9 mM L⁻¹) and corresponding thinning behaviour between two plates of extensional viscometer.</i>	210
Figure 7-5: <i>Particle-bubble impact behaviour and corresponding thinning, and molecular structure of the bubble film.</i>	211

Figure 7-6: Extensional viscosity as a function of SDS concentration for HPMC solutions.	212
Figure 7-7: Extensional viscosities of HPMC-water solutions at different strains with different level of SDS concentrations: (a) 0.065% (w/v), (b) 0.26% (w/v), (c) 0.52% (w/v) and (d) 1.0% (w/v).	215
Figure 7-8: Particle-bubble impact behaviour, visual extensional flow behaviour, schematic graphical extensional flow behaviour and schematic molecular-level association at SDS concentrations, < cac, at cac and > cac.	216
Figure 8-1: Total weight of uncoated and coated 1,2 and 3 mm diameter particles with HPMC-1.0% (w/v)-9 mM L ⁻¹ SDS bubbles.	222
Figure 8-2: Number of droplet-particle impacts vs. amount of coating deposited in a droplet based particle coating system. This graph is reproduced from (Ström et al., 2005).	223
Figure 8-3: Coating thickness per particle-bubble contact for 1, 2 and 3 mm diameter particles.	224
Figure 8-4: (a) Uncoated glass particle, (b) HPMC-SDS bubble film coated glass particle and (c) Hydroxypropyl cellulose (HPC) droplet coated glass particle. The SEM image of the HPC droplet coated glass particle was reprinted from (Ström et al., 2005).	225
Figure 8-5: Backscattered electron mode SEM images of transversal cross-section of HPMC coated Cellulose Acetate Phthalate particle.	226
Figure 8-6: Edge morphology of (a) HPMC-SDS, (b) NaCAS, (c) NaCAS-SDS and (d) NaCAS-PEG-SDS bubble coated 1 mm diameter glass particle.	227
Figure 8-7: Uncoated and HPMC bubble film coated porous glass particle.	228
Figure 9-1: Conceptual industrial-scale powder coater using bubbles.	236
Figure 9-2: Conceptual micro-scale phenomena occurring in conceptual rotating drum-based industrial-scale particle coater.	238

LIST OF TABLES

Table 2.1: <i>Particle coating attributes.</i>	13
Table 2.2: <i>Summary of the research questions to be investigated in this thesis.</i>	42
Table 3.1 <i>Comparative contact angle values of silanised and surfactant foam coated silanised glass powders or particles using different techniques.</i>	67
Table 4.1 <i>Viscosities and surface tensions of HPMC (PC603) solutions at 20°C, with standard error (n=3).</i>	87
Table 4.2: <i>Experimental plan, air:liquid ratios and two T-junctions.</i>	88
Table 4.3 <i>Experimental plan, polymer concentrations.</i>	89
Table 4.4 <i>Experimental plan, nozzles.</i>	89
Table 5.1 <i>Variables involved in bubble particle impact experiments.</i>	112
Table 6.1: <i>Range of experimental condition responsible for particle capture (C), particle slide-off (L), bubble burst (B) and self-healing bubbles (S).</i>	149
Table 6.2: <i>Conditions for self-healing to occur. Bubble size was 6.5 ± 1.0 mm. For the statement $HPMC < 1.0\%$ (w/v), this means the three solutions at concentrations of 0.065, 0.26 & 0.52% (w/v).</i>	151
Table 6.3: <i>Counts of bubble burst (B), particle capture (C), particle slide-off (L) and bubble self-healing (S) for particle-bubble impact behaviours using 1 mm spherical hydrophilic glass particles. Drainage time of a bubble was controlled between 2 and 5 seconds to keep the bubbles reproducible.</i>	159
Table 6.4: <i>Relevant dimensionless numbers for a particle impacting a bubble and forming a stretched film tube. This work was done by Prof Jim R. Jones.</i>	184
