PARTICLE COATING USING FOAMS AND BUBBLES

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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 ≥ *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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