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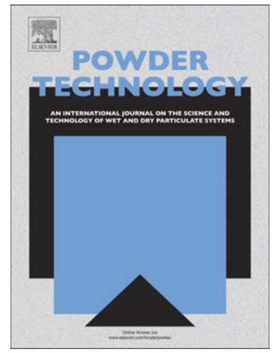

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Peter M. Ireland, Masayo Noda, Edmund D. Jarrett, Syuji Fujii, Yoshinobu Nakamura, Erica J. Wanless, Grant B. Webber

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Electrostatic formation of liquid marbles – Influence of drop and particle size

Peter M. Ireland[1,2,a], Masayo Noda[3], Edmund D. Jarrett[1,2], Syuji Fujii[3], Yoshinobu Nakamura[3], Erica J. Wanless[1,4], Grant B. Webber[1,2]

[1]Priority Research Centre for Advanced Particle Processing and Transport
[2]Discipline of Chemical Engineering, University of Newcastle, Australia
[2]Department of Applied Chemistry, Faculty of Engineering, Osaka Institute of Technology, Japan
[4]Discipline of Chemistry, University of Newcastle, Australia

[a]Corresponding author: Peter.Ireland@newcastle.edu.au

Abstract

We report the first study of the influence of drop and particle size on the electrostatic manufacture and subsequent stability of liquid marbles. It is clear from this study that the 'rules' for electrostatic formation of liquid marbles are quite different for those for conventional direct-contact manufacture. Formation of liquid marbles was observed when an earthed water drop of volume 3 – 7 µL was brought into proximity with a bed of highly-charged polystyrene particles of diameter 22 – 153 µm. Under appropriate conditions the particles jumped to and coated the drop, producing a particle-liquid aggregate that dropped to the bed surface in the form of either a stable liquid marble or a particle-stabilised sessile drop. The subsequent evolution of the physical dimensions of the metastable aggregate was measured as the liquid drained into the bed, and its stability assessed. Formation of stable liquid marbles appeared to occur more easily for smaller drops and larger particles, and some of these considerably exceeded the conventionally-understood limit for the ratio of particle to drop size of stable liquid marbles.

Keywords: Particles, powder, electrostatics, liquid marble

1. Introduction

The formation of liquid-hydrophilic particle agglomerates via an electrostatically-driven process was first described by our group in 2013 [1]. The resulting metastable agglomerate bore some resemblance to the liquid marbles – liquid drops encased in a shell of non-wetting particles – first observed over a decade ago [2], which have remarkable physical properties [3, 4] and a variety of current and potential applications [4-8]. Unlike these 'traditional' liquid marbles, the agglomerates in our previous study consisted of a water droplet entirely filled with hydrophilic silica particles – a result that cannot be achieved using the conventional marble formation method of rolling the drop on a particle bed (as the water drop simply soaks in). Our electrostatic process offers both a new and very different method for forming traditional liquid marbles with hydrophobic particles, and the prospect of a new class of liquid marble complexes with layered structures, for a variety of applications [9].

2. Materials and methods

Here we briefly describe the electrostatic formation technique, then present some of the results from experiments carried out using micrometre-sized monodisperse polystyrene (PS) particles (Microbeads, Norway, see Fig. S1 of the Supplementary Material). The particles were washed using distilled water, before use to remove the anionic sodium dodecyl sulfate and cellulose stabiliser used in manufacture (ten cycles of centrifugation and supernatant replacement), and had volume average diameters (D_v) of 22, 42, 85 and 153 µm as measured by laser diffraction particle size analysis in water (see Fig. S2 in the supplementary material).

These particles had a hydrophilic surface chemistry; since the particles were water-dispersible (for particle size measurement) some residual sodium dodecyl sulfate or cellulose stabiliser must remain. However the surface roughness of the dried PS particle powder tended to produce a metastable Cassie-Baxter wetting regime [10, 11]. They therefore exhibited an effective or apparent hydrophobic