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Dispersion of a semi-solid binder in a moving powder bed during detergent agglomeration

Menan Balashanmugam[a], *Yuen Sin Cheong*[b], *Zayeed Alam*[c], *Michael J. Hounslow*[a], *Agba D. Salman*[a,*]

[a] *Department of Chemical and Biological Engineering, The University of Sheffield, UK*
[b] *Procter and Gamble, Beijing Technical Centre, China*
[c] *Procter and Gamble, Newcastle Innovation Centre, UK*

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ABSTRACT

Detergent agglomeration often involves the use of a highly viscous semi-solid (paste) binder. Such binders do not penetrate or disperse into a powder bed in the absence of an external force. Therefore mechanical dispersion is often employed to facilitate binder dispersion. Understanding the binder dispersion process is vital in ensuring consistent product quality. The present study aims to describe how viscous surfactant binders will undergo fragmentation/breakage within the mixer. The semi-solid binder can be considered to be “particles” and these powder coated binder particles (PCBPs) undergo a size reduction process with time. Other factors that influence the rate at which this size reduction process will occur include impeller speed, particle size and morphology.

A typical detergent formulation will consist of a mixture of surfactant, zeolite (powder) and soda ash (powder). Two different grades of soda ash powder were studied: 130 μm light ash particles and 11 μm ground ash particles. This study reveals that larger particles maybe capable of exerting larger forces leading to more rapid breakage and deformation of the coated semi-solid binder fragments. This study also reveals that rougher particles are capable of penetrating the surface of the binder to a greater extent than smoother ones. In the case of zeolite, due to its smaller, more spherical particles and compact structure, the intermolecular forces within the semi-solid binder may be able to oppose the applied force (impact from the particles at the boundary) to a greater extent. This explains the slow change in the mean diameter of the zeolite PCBPs with time compared with the other two powders. At higher shear rates, there does not appear to be a significant increase in the final mass of the PCBPs when compared to the trials done at lower shear, instead the time taken to reach steady state in terms of both size and mass is shortened for all three powders, and for light and ground ash the lifespan of the PCBPs are shortened significantly, as the system passes the nucleation step and enters the wet-agglomerate regime.

To conclude larger and rougher particles, with better flowability will disperse the highly viscous binder more effectively in a moving bed of powder. A high shear rate is recommended for better initial dispersion of the binder into powder formulations that consist of a large proportion of fine material.

* *Corresponding author*. Tel.: +441142227560; fax: +441142227501.
E-mail address: a.d.salman@sheffield.ac.uk (A.D. Salman).

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1. Introduction

Granulation is used to convert fine powders into more free flowing, easy-to-process granules. There are two different types of granulation processes: wet and dry. The wet granulation process involves mixing the powder with a liquid binder. The granulation process is a multi-scale problem. The macro-scale wetting kinetics (which are influenced by binder addition, binder dispersion and mixing rates) have a direct influence on the micro-scale phenomena which includes nucleation, growth, coalescence, consolidation and breakage. These ultimately influence the properties of the granular product.

A high shear mixer is a commonly used piece of equipment in granulation. High shear mixers contain mechanical blades that exert both shear and impact on the mixture that is being granulated. As mixing progresses and binder starts to disperse into the powder bed, nucleation sets-in, followed by growth, coalescence, consolidation and breakage.

A key difference in detergent agglomeration compared to most agglomeration processes conducted in the food and pharmaceutical industries is the high viscosity of the semi-solid surfactant binder. In comparison to aqueous binders, these surfactants are about 10^4 times more viscous. This makes handling the surfactant binder a challenge. Vast majority of the agglomerated dry laundry powder is made using the neutralised form of LAS acid (usually its sodium salt) (York, 2003). To increase the performance of the detergent, the loading (concentration) of the surfactant in the detergent granules has to be maximised. To achieve this most surfactants are added in their highly concentrated (paste) form. This means that diluting the binder to improve paste dispersion, by reducing its viscosity, is not an option. One of the challenges associated with the use of a highly viscous paste is ensuring its subsequent dispersion within the mixer.

Successful granulation is largely dependent on the inclination of particles and binder to attract and subsequently remain bound to one another. There are several well established binding mechanisms during agglomeration, including adhesion and cohesion forces, interfacial forces and capillary pressure, solid bridges, attractive forces between solid particles, and interlocking bonds (Rumpf, 1962). General agglomeration using a conventional solvent binder or aqueous binder consists of three main stages namely wetting and nucleation (Fig. 1), consolidation and growth and finally breakage and attrition. This study focuses primarily on the nucleation step. Factors which are likely to influence the nucleation step for paste binders include forces of attraction between the primary particles, and adhesion and cohesive forces of the paste binder. The dispersion mechanism of highly viscous surfactant binders is somewhat different.

Previous studies conducted by Rough et al. (2003, 2005a,b,c,d) have looked into the granulation of fine powders using a highly viscous surfactant binder. Their work confirmed the existence of several regimes including a powdery, crumble, agglomerate, wet agglomerate and dough state, similar to most immersion granulation processes outlined by Iveson et al. (2001). The identification of these regimes was done in a qualitative manner by visually examining optical micrographs of the granular samples. Their study focused mainly on looking at how the sample progressed through these different regimes/states. An indirect method of quantitatively describing the rate of progress into different regimes was devised by observing changes in the bulk granular aerated and tapped densities. They use the Hausner ratio and a logarithmic compaction type analysis suggested by Orr (1966) (determined from the results of the tapping analysis) to explain changes in the mechanism of granulation.

1.1. *Hypothesis for nucleation and initial binder dispersion*

The present study focuses primarily on the nucleation process and how this impacts on the initial dispersion of a semi-solid paste binder into a powder bed. Nucleation is the term used to describe the adhesion of primary particles in the presence of a binder or fluid. The distribution of the wetting/binding agent has a profound influence on the size distribution of the nuclei. The extent to which the powder is covered and the rate at which this happens is important in determining the physical properties of the granular product. Conventional methods of characterising the process of wetting include analysing

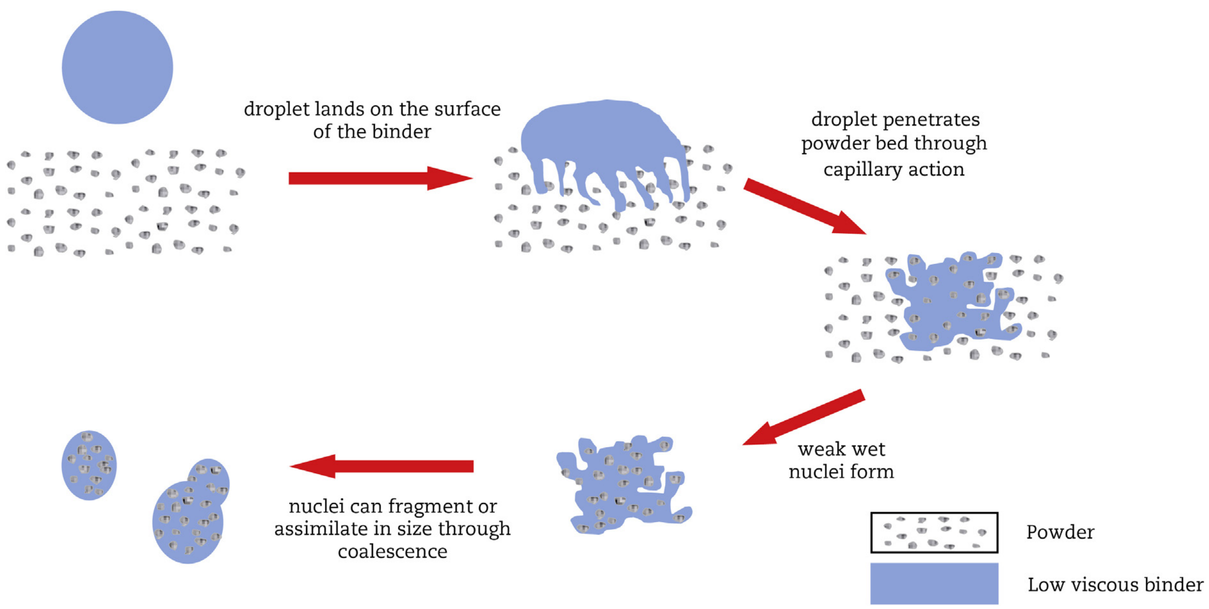

Fig. 1 – Granulation mechanism for low viscous binders.