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Model-based design and control of a continuous drum granulation process

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ABSTRACT

This paper is concerned with enhanced process design and control of a multiple-input multiple-output (MIMO) granulation process. The work is based on a first-principles mechanistic three-dimensional population balance model (3D-PBM), which has been previously validated against experiments at the laboratory-scale for various operating conditions and formulations. The main objective of this study is via a novel process design, to control and operate the granulation process under more optimal conditions. Novelty of the work lies in the usage of the validated 3D-PBM to extract suitable multiple control-loop pairings from which an overall control loop performance is qualitatively and quantitatively assessed. Results show that for most existing granulation process configurations, enhanced control-loop performance is not achieved and as a result an alternative process design strategy is necessary. The proposed design demonstrates increased efficiency in the control and operation of the granulation process, which is required for further efficient control and operation of subsequent downstream processes.

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Keywords: Granulation; Multi-dimensional population balance model; Control studies; Process design; Model validation

1. Introduction and objectives

Granulation is a particle design process of converting fine powder into larger free-flowing agglomerates. It finds application in a wide range of industries (e.g. pharmaceuticals, fertilizers and minerals). Granulated products often have notable improvements compared to fine powders and these include increased bulk density, improved flow properties, controlled dissolution and uniformity in the distribution of multiple solid components. Granulation processes have been ubiquitous in the industry for many years with significant research undertaken to gain further insight into the underlying phenomena occurring during the process. However, industrial granulation processes are operated inefficiently and the resulting wide distribution of granule properties is often the cause of large recycle rates in continuous processes and high rejection rates in batch processes (Ivenson et al., 2001). Therefore, an integrated systems approach to design and control the process will be a crucial aid to mitigate this situation (Mort, 2005; Bardin et al., 2004; Knight et al., 1998; Litster, 2003; Cameron et al., 2005; Stepanek et al., 2009).

In a continuous granulation process (which this study deals with), feed material in the form of fine powder is continuously introduced into the granulator as granulation occurs. The granulator is fitted with several spray nozzles in different positions through which the liquid binder is introduced into the granule bed. The granules formed are then dried and classified based on product specification(s). Granules that do not conform to product specification(s) are recycled, reprocessed and/or discarded. Prior to the actual design of the controller for the granulation process, it is important to know how well the process can be controlled and what factors may hinder the control loop performance that may be achieved in reality. It is also imperative that appropriate process inputs and outputs are selected for control purposes and also that they are paired correctly as incorrect pairings may limit and hinder control loop performance (Sourlas and Manousiouthakis, 1995; Cui and Jacobsen, 2002; Kariwala, 2007). Therefore, a plant is said to be controllable if there exists a controller that can in principle, be able to achieve a certain output state via certain admissible input changes (Eek and Bosgra, 2000). Controllability is an intrinsic plant property and is determined

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