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Characterizing mixing and lubrication in the Bohle Bin blender

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Abstract

Mixing and transport of a cohesive powder are experimentally characterized in a laboratory-scale Bohle Bin blender. The cohesive powder is a blend of Avicel, lactose, and magnesium stearate (MgSt). The effects of vessel fill level, rotational speed, mixing time, and the presence of baffles on mixing are characterized by quantifying MgSt distribution using Near Infrared (NIR) spectroscopy. Results show that the relative standard deviation (RSD) decays faster (on a per revolution basis) and further (lower plateau) at higher rotational speeds. This result indicates a dependence of mixing of cohesive materials on shear. We find that fill level has a strong impact on mixing rate; the higher the fill level, the slower the mixing. Segregated regions are observed at the center of the blender for high fill levels at low rotational speeds. The presence of baffles seems to hinder mixing; the RSD decays are slower and leveled at a higher plateau when baffles are used. Concentration profiles data shows that, at high fill levels, baffles promoted the formation of segregated region at the center of the mixer.

Keywords: Bin blender; Powder mixing; Magnesium stearate; Near Infrared; Lubrication

1. Introduction

Particle blending is a required step in a variety of applications spanning the ceramic, food, glass, metallurgical, polymers, and pharmaceuticals industries. A common type of batch industrial mixer is the tumbling blender, where grains flow by a combination of gravity and vessel rotation. Although the tumbling blender is a very common device used to mix granular materials, surprisingly little is known about mixing and segregation in these devices (for a review on solid mixing devices, see [1–4]). The flow pattern within these blenders is believed to consist of a thin, rapid flow region near the surface, a nearly non-deforming region beneath that rotates with the container as a solid body, and a narrow transition region between, which is characterized by high shear and density gradients [5,6]. Particles within the rapid flow region are thought to be highly dilated and, therefore, predominantly interact by collision, rather than by enduring contact. The main transport mechanisms, nevertheless, are yet to be well characterized in realistic blenders. To date, the design and control of three-dimensional (3D) blenders have been based more on trial and error than on quantitative or analytic methods. Even quantitative characterizations of mixing performance as a function of the most basic parameters, such as vessel speed or filling level, are scarce in the literature ([7–12]).

The Bin blender is one of the most common tumbling blenders currently used in the pharmaceutical industry. While this device has received considerable attention lately for increased convenience and safety, little is known about the effect of fundamental parameters such as blender geometry, speed, fill level, or mixing performance. In fact, published studies have been limited to the Gallay Bin blender [11,12]. To the best of our knowledge, no published reports exist on the Bohle design studied here.

Unless the blending process is properly designed and controlled, the result is often a mixture with significant composition fluctuations. In the pharmaceutical context, inefficient blending can lead to increased variability of the active component, threatening the health of patients. Inefficient blending has two main causes: (i) poor equipment design or inadequate operation and (ii) particle segregation (driven by

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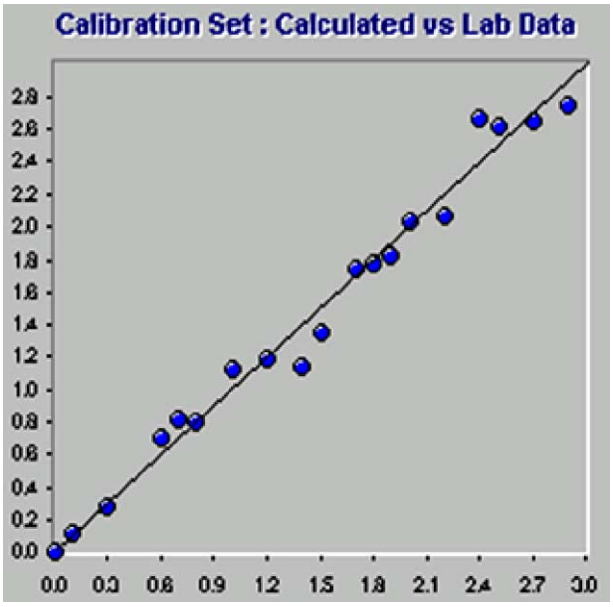

Fig. 1. Near Infrared (NIR) spectroscopy calibration curve. The ordinate corresponds to predicted values and the abscissa corresponds to known values of MgSt. Blue circles correspond to prepared samples of known MgSt concentration. Solid line represents the calculated values of MgSt concentration. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

differences in material properties). Additional problems may occur when a lubricant is added to the mixture (as in the case of most pharmaceutical formulations).

Lubricants such as magnesium stearate (MgSt) work by interposing a film of low shear strength material at the interface between the tablet mass and the die wall. The addition of dry lubricants allows compression at lower pressure and reduces the generation of heat during tablet compression. The effect of the lubricant depends on the amount and intensity of shear energy that is applied to the lubricated mixture. Although small amounts of lubricant are used (around 1%), it is known that the insolubility of this material poses a problem to the penetration of the solid dosage form by the gastrointestinal fluids intended to dissolve it [13]. Lubricants can also impart other undesirable characteristics to tablets. The interactions between the lubricant and excipient or between the lubricant and the active ingredient may cause insufficient mechanical strength of tablets and capsules. Poor lubrication also leads to variability in the compaction step (i.e. the tablet will stick to the press) and it may hinder powder flowability. Over-lubrication is also a situation that must be avoided. This occurs whenever the addition of dry lubricant tends to coat the particles of the formulation, thus decreasing particle binding and the strength of the tablets. This results in a decrease in tablet solubility, which affects dissolution time. Thus, it is also important to monitor the homogenization of lubricants during the mixing process.

In this paper, we experimentally investigate the mixing of a cohesive material in an industrially relevant blending device: the Bohle Bin blender. We do so by studying the homogenization process of a powder mixture containing the lubricant MgSt. The operational parameters are mixing time, fill level, rotational speed, and the presence (or absence) of baffles. We use extensive sampling to characterize mixing by tracking the evolution of MgSt using a Near Infrared spectroscopy detection method.

2. Near Infrared spectroscopy

Near Infrared (NIR) spectroscopy is used to quantify MgSt in a powder matrix composed of 64% of Avicel PH101 (Microcrystalline Cellulose), 35% of lactose, and 1% of MgSt. This NIR assay is presented in detail elsewhere [14]; only a brief description is given here. The method begins by selecting a calibration sample set according to the lubricant concentration. Samples are prepared by keeping the ratio of Avicel to lactose randomized in order to minimize effects of imperfect blending of excipients during the actual experiments. We then increase the concentration of the lubricant in 0.1 percentage intervals from the control value 0% (no MgSt) to 3%. Partial-least squares method (with a second derivative treatment) is applied to the full NIR portion of the spectrum (1140–1830 nm). Mathematical regression is performed on the calibration

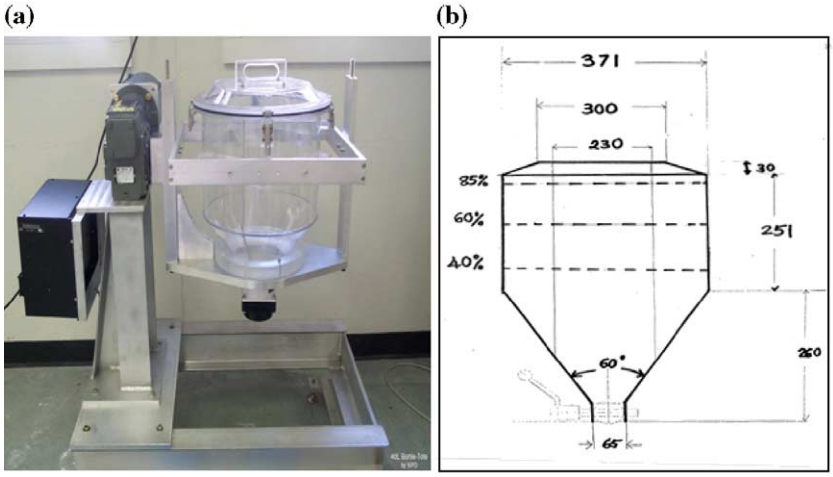

Fig. 2. (a) A snapshot of the Bohle blender in the laboratory. (b) Schematic and dimensions (in mm) of the Bohle blender.