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Rapid communication

Use of a static eliminator to improve powder flow

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ABSTRACT

Glidants and lubricants have long been used to improve the flow and processing of pharmaceutical and other powder blends. In this letter, we find that similar improvements can be attained, without additives, by using a simple static eliminator. These results indicate, first, that electrostatic effects on powder blends may be a significant cause of powder aggregation and flow instabilities, and second, that common additives such as magnesium stearate, colloidal silica, and talc may have as their chief effect the reduction of static. This suggests both that intelligent placement of static eliminators can eliminate the need for some of these additives and that judicious engineering of ionic and cationic additives may be effective in improving flow of "clingy" materials.

1. Introduction

Problems with electrostatic charge accumulation range from catastrophic events such as dust explosions and fires (Palmer, 1973), to more mundane, but nonetheless serious, problems including jamming (Eilbeck et al., 2000; Nishiyama et al., 1998; Rowley, 2001; Mullarney and Hancock, 2004), agglomeration (Shinbrot et al., 2006), spontaneous segregation (Mehrotra et al., 2007), flow instabilities (Al-Adel et al., 2002; Liang et al., 1996), and material degradation (Vinod et al., 1997; Alebi-Jureti et al., 2000). Longstanding efforts to mitigate the effects of static charges in powder beds (Taillet, 2003; Matsusaka and Masuda, 2003) have included both the use of antistatic agents (Orband and Geldart, 1995) and the direct elimination of charges using passive, active, or radioactive static eliminators (Revel et al., 2003; Kodama et al., 2002). Although there remains some uncertainty concerning the level of efficiency of different static control alternatives, these approaches have been shown to significantly address charge accumulation problems, most recently including improving powder flow (Orband and Geldart, 1995). In the present study, we focus on the specific issue of how well static elimination alone improves powder flow, as compared with additives such as glidants that have traditionally been believed to mechanically reduce friction and cohesion between grains (Egermann and Frank, 1990; Kornchankul et al., 2002; Otsuka et al., 1993). We find, surprisingly, that static elimination alone provides as great an improvement to flow as do a variety of glidants, lubricants and other additives. This suggests that powder flow and electrostatics may be more intimately related than has been previously appreciated. In this brief paper, we first describe experiments performed using 10 blends of excipients, active pharmaceutical ingredients, and flow additives. Next, we evaluate the flow behavior of the blends with and without static elimination, and finally we draw conclusions.

2. Materials and methods

Nine different blends of pharmaceutical powders were prepared by mixing the blends for 30 min in a V-blender with an intensifier bar. A detailed discussion of the mixing equipment appears in a previous study (Pingali et al., 2009), and the compositions of ingredients in each blend are as shown in Table 1. Pure ingredients (blends #1–5) are taken directly from the supplier bin without tumbling. In each experiment, a sample of 5 lb blend was prepared for testing, and the sample was tumbled in an acrylic drum, 20 cm in diameter and 42 cm in length as shown in the schematic of Fig. 1(a). The drum was tumbled at 14 rpm for all experimental runs. Concentric holes were drilled at either end of the drum so that ions from an active static eliminator (model: 7901; manufacturer: EXAIR Corp.; location: Cincinnati, OH) could be introduced while the drum was tumbled. Compressed air was used to inject ions produced by the static eliminator into the rotating cylinder.

To evaluate flow behavior, we make use of a result documented elsewhere (Faqih et al., 2006a,b): that the "Flow Index" of a powder

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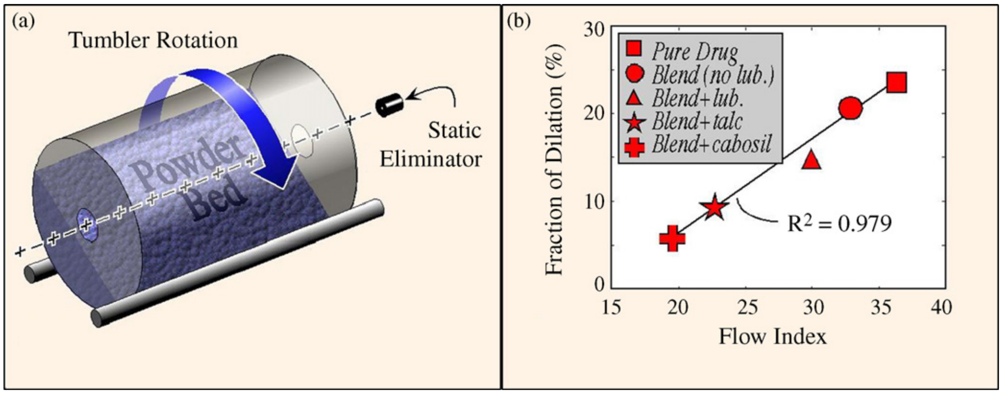

Fig. 1. (a) Schematic of acrylic tumbler with static eliminator. As indicated, the tumbler has holes drilled in its endplates so that ionized air can be blown from the static eliminator past the powder bed. (b) Plot of linear Fraction of Dilation of the powder bed vs. the Flow Index, as measured by a Gravitational Displacement Rheometer: lower Flow Index represents more freely flowing blend. The "Pure Drug" here is micronized acetaminophen, the "Blend (no lub.)" is a 50-50 blend of Pharmatose and Avicel 102, and the remaining blends include 1% magnesium stearate ("lub."), talc, and Cab-o-Sil. For all of these blends, and other blends studied elsewhere (Pingali et al., 2009), there is a strong linear correlation between Flow Index and fraction of dilation.

Table 1
Compositions of test blends by weight. Lactose is milled (67 μm mean diameter Pharmatose, 125 M, DMV International Inc.); μAPAP is micronized acetaminophen (CAS-103-90-2; Mallinckrodt Inc.); CMC is carboxymethyl cellulose (Avicel 102, FMC, Rothschild, WI); sAPAP is semifine acetaminophen (CAS-103-90-2; Mallinckrodt Inc.); fastflo is Fast-flo lactose (Foremost farms, Newark, NJ: 100 μm spherical); MgSt is magnesium stearate (CAS-557-04-0; Mallinckrodt Inc.); talc is from (Fisher, T4-500; Laboratory grade); and silica is fumed silica (Cab-o-Sil, Laboratory grade). Magnesium stearate is a standard lubricant, talc and fumed silica are glidants commonly used in pharmaceutical, cosmetic and other industries.

Blend	lactose	μAPAP	CMC	sAPAP	fastflo	MgSt	talc	silica
#1	100%							
#2		100%						
#3			100%					
#4				100%				
#5					100%			
#6	45.5%	9%	45.5%					
#7	45 %	9%	45 %			1%		
#8	44.5%	9%	44.5%			1%	1%	
#9	44 %	9%	44 %			1%	1%	1%

is, to a very high degree of accuracy, linearly related to the fractional volumetric expansion of the powder as it flows in a drum tumbler. The Flow Index is a measure of how freely a powder flows, performed using a Gravitational Displacement Rheometer (GDR) (Faqih et al., 2006a,b), which evaluates the statistics of avalanche sizes in an instrumented tumbling blender. For typical pharmaceutical powders with bulk densities in the range of 0.4–0.6, a freely flowing powder has a low index (typically below 25), and a cohesive, irregularly flowing powder has a high index (typically above 30). In Fig. 1(b), we confirm that dilation fraction is linearly correlated with measured Flow Index for several of our samples, where the Flow Index is measured in the GDR as in the prior literature. The fraction of dilation shown is measured by digitally photographing the endplate and measuring the fraction by which the mean height of the bed evaluated from the photograph increases as compared with the initial height of the bed. The use of dilation as a surrogate for the Flow Index permits us to evaluate the effects of additives and processing changes (especially the incorporation of a static eliminator) inexpensively, rapidly, and without making modifications that might interfere with the calibration of the GDR.

3. Results and discussion

In Fig. 2 we show results of our experiments for pure Pharmatose excipient (blend #1) and pure micronized APAP (blend #2). Evidently in both cases, the use of a static eliminator substantially decreases the fraction of dilation of the bed, and correspondingly improves the flow, both as inferred from Fig. 1(b) and from visual observation of the regularity of the powder flow during the experiment. Multiple-component blends also show flow improvements, summarized in Fig. 3.

Standard deviation of all dilation datasets for a given blend are ~1% of the mean, so with the exception of blends 5, 8 and 9, the static eliminator significantly improves flow. Blend 5 consists of pure Fastflo lactose, which has been granulated to improve flow already, and

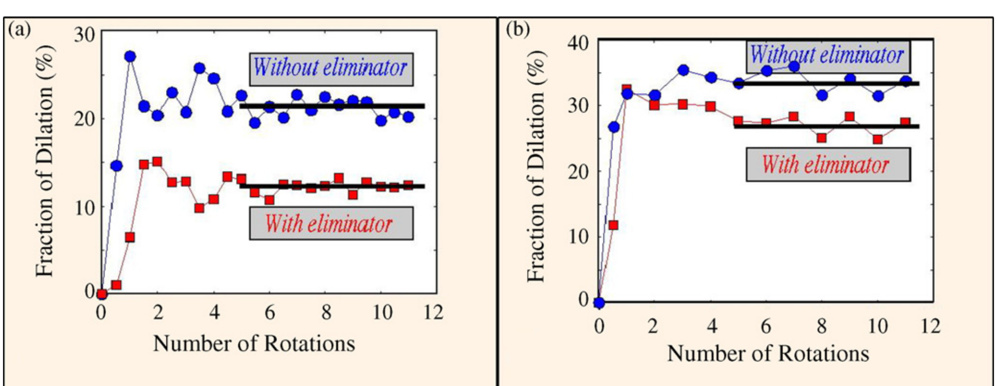

Fig. 2. Dilation fraction vs. tumbling time. Results show the characteristic change in bed expansion under the influence of the static eliminator for (a) pure lactose (b) pure micronized acetaminophen. Black lines indicate average dilations after the bed has reached steady state, showing lactose has a difference in fractional dilation of 9 ± 1%, and acetaminophen has a difference of 6 ± 1%.

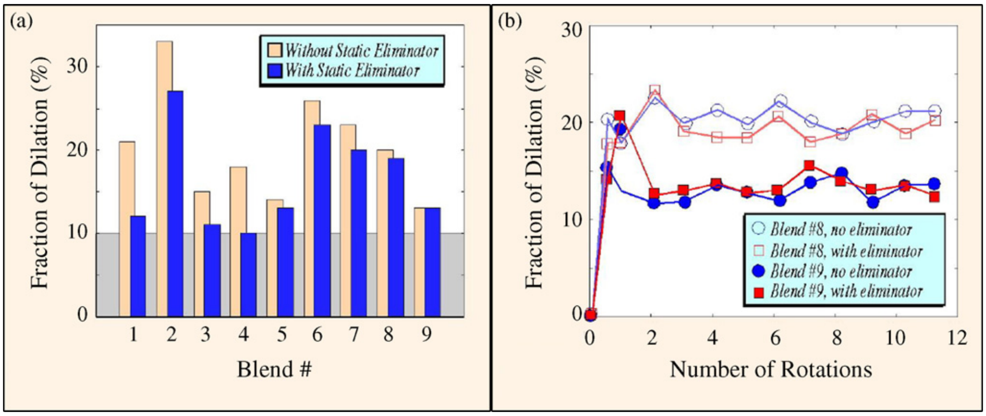

Fig. 3. Dilation fractions with and without static elimination. (a) Dilation fraction for all nine blends studied. Gray area indicates the lowest dilation – and hence the most freely flowing case – seen, which is attained for pure semifine acetaminophen. (b) Dilation vs. rotations for blends 8 and 9, containing the highest concentration of flow improving additives.

blends 8 and 9 have the highest concentrations of flow enhancing additives. Thus Fig. 3(a) demonstrates that for most blends studied, static elimination improves flow. In fact, the best flow is seen for blends 3 and 4, respectively an excipient and an active powder without flow enhancing additives but with a static eliminator. Moreover, Fig. 3(b) illustrates that when a full complement of lubricants and glidants are added to the blend, the static eliminator does little. This indicates that static elimination and flow additives seem to some degree to be redundant, but strongly suggest that the mechanism by which additives improve flow is connected to static charge elimination.

The results of this brief report can be summarized as two main observations. First, static elimination alone substantially improves flow of a variety of pharmaceutically relevant powders. Second, static elimination does little or nothing to improve flow of powders containing traditional flow enhancing additives. This latter result provides the intriguing direction for future research that either flow additives may have as an incidental side-effect that they may prevent powders from tribocharging—and hence the eliminator does little to improve the flow, or that the improvement in flow produced by flow additives may be closely tied with the concurrent reduction in charge. Since it is well known that charging significantly degrades powder flow (Al-Adel et al., 2002), this raises the question of what is the relation between flow additives and electrostatics. Do additives reduce friction between grains, which incidentally reduces tribocharging, or do additives mitigate tribocharging, thus improving flow through another means? Or, may be, both? The answer to this question is fundamental to understanding how powder flow and charge interact.

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