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RESEARCH ARTICLE

Application of Principal Component Analysis (PCA) to Evaluating the Deformation Behaviors of Pharmaceutical Powders

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Abstract
Introduction This study uses principal component analysis (PCA) to investigate deformation during powder compaction, in order to classify common pharmaceutical materials according to their relative plasticity.
Methods A variety of mechanical measurements were used during PCA modeling, including both applied force-dependent measurements and deformation parameters derived from various consolidation models. The applied force-dependent measurements included solid fraction, density change during elastic recovery, work of compression (w_c), work of decompression (w_d), normalized radial tensile strength ($\sigma T/\sigma T, \varepsilon=0$), elasticity, and the work of compression and decompression ($w_{c/d}$). The models of consolidation included those proposed by Heckel, Walker, Alderborn, Gurnham, and Denny's proposed modification to the Heckel model. The initial PCA model was calibrated based on 12, well-characterized pharmaceutical materials with a wide span of plastic, brittle, and elastic deformation properties.
Results and Conclusions It was found that the first principal component seemed to be consistent with the relative plasticity of each material predicted by traditional methods. The variables contributing most to the variance explained by the first PC were found to be the c value from Gurnham model, w_c, and $w_{c/d}$. Further analysis of five additional materials indicated that the c value, alone, provided adequate differentiation of the materials' relative plasticities. The advantages of multivariate analysis in analyzing the mechanical data and future application of PCA modeling are also discussed.

Keywords Compression · Powder compaction · Principal component analysis · Plastic deformation · Particle consolidation · Tableting

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Introduction

Pharmaceutical tablets constitute a very popular dosage form and account for almost 50 % of all the solid pharmaceutical products currently available in the market [1]. Although they have been in use for many years, they are still developed using trial-and-error methods. A primary challenge is to develop a tablet with acceptable mechanical properties without interfering with its release behavior. This challenge depends on the deformation behaviors of the drug and the excipients used in the formulation as well as the manufacturing conditions. As a part of developing a robust drug product and manufacturing process within the framework of quality by design, an in-depth understanding of both the raw material attributes and critical process parameters is required. In this work, a multivariate approach is used to investigate the deformation behavior of the materials.

When powders are compressed in a die, three general types of deformation behavior are observed: brittle