# BRINGING PARTICLE PROPERTIES INTO DESCRIPTIONS OF POWDER BEHAVIOR VIA THE ENHANCED CENTRIFUGE METHOD

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## ABSTRACT

Many industrial processes involve powders in some form when making products, and the behavior of the powders processed is impacted by the adhesion of the individual particles which comprise it. This adhesion behavior, in turn, is critically influenced by the complementarity between the topography of a surface and the shape and roughness of the particles that adhere to that surface. Problems such as poor flowability, dust hazards, and equipment wear arise due to uncontrolled particle adhesion and can lead to production challenges. Computational models have been developed to predict the behavior of highly idealized powders (i.e., powders comprised of simple geometries such as spheres) under various processes but are limited in their ability to model and optimize the manufacturing and handling of powders comprised of many complex particles. This work focuses on further developing an experimental and modeling framework, called the Enhanced Centrifuge Method (ECM), that maps particle-scale and surface properties onto experimentally-validated 'effective' adhesion distributions that describe the adhesion between particles in powders. These distributions represent an engineering approach that allows powders comprised of particles of complex shape and roughness, which are challenging to model, to be described as if they were perfect, smooth spheres, which are comparatively simple to model. The complexity associated with the shape and size distributions of the individual particles is captured by the 'effective' adhesion parameters. These 'effective' adhesion parameter distributions provide a quantitative guide as to how the specific particle properties are interacting with the surface topography which directly impacts the overall powder adhesion. The initial framework of the ECM is constructed around characterizing the van der Waals adhesion of silica and polystyrene powders. The impact of the surface topography and the particle properties of each of the powders is captured in 'effective' Hamaker constant distributions. These distributions provide a quantitative guide for specifically how the particles interact with the surface topography based on the respective scales of the particle and surface features. The ECM framework is further adapted here to investigate the effects of topographical changes of stainless steel due to polishing on the adhesion properties of

three different pharmaceutical powders to the stainless steel. In this adaption of the ECM framework, the force of adhesion was described by modifying the Johnson, Kendall, and Roberts (JKR) model describing elastic-like particle contact to a flat plate. Within the modified JKR adhesion description, the work of adhesion is tuned to be an ‘effective’ work of adhesion parameter. These size-dependent ‘effective’ work of adhesion distributions provide a quantifiable measure of the change in the powder and surface adhesion that reflects the size, shape, and topographical features on the powder and surface with which the powder interacts. To investigate environmental condition effects on the adhesion properties, the ECM framework is also extended to characterize the effect humidity has on altering surface and particle interactions of the three pharmaceutical powders to stainless steel. In addition to the work with the pharmaceutical powders, the investigation of the effect of humidity on the powder’s adhesion includes a study the influence of water on the interactions between silica particles and a silica substrate. In all cases, the ‘effective’ adhesion force distributions developed through the ECM provide the ability to quickly determine quantitatively how environmental and process conditions alter particle and surface properties, and overall powder behavior.